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DEFINITION OF EXPERIMENTS AND INSTRUMENTS FOR A COMMUNICATION/NAVIGATION RESEARCH LABORATORY

VOLUME IV

PROGRAMMATICS

STUDY REPORT

DR MA - 04

October 1972

PREPARED FOR MARSHALL SPACE FLIGHT CENTER
UNDER CONTRACT NO. NAS 8 - 27540

TRW SYSTEMS GROUP

ONE SPACE PARK • REDONDO BEACH CALIFORNIA 90278

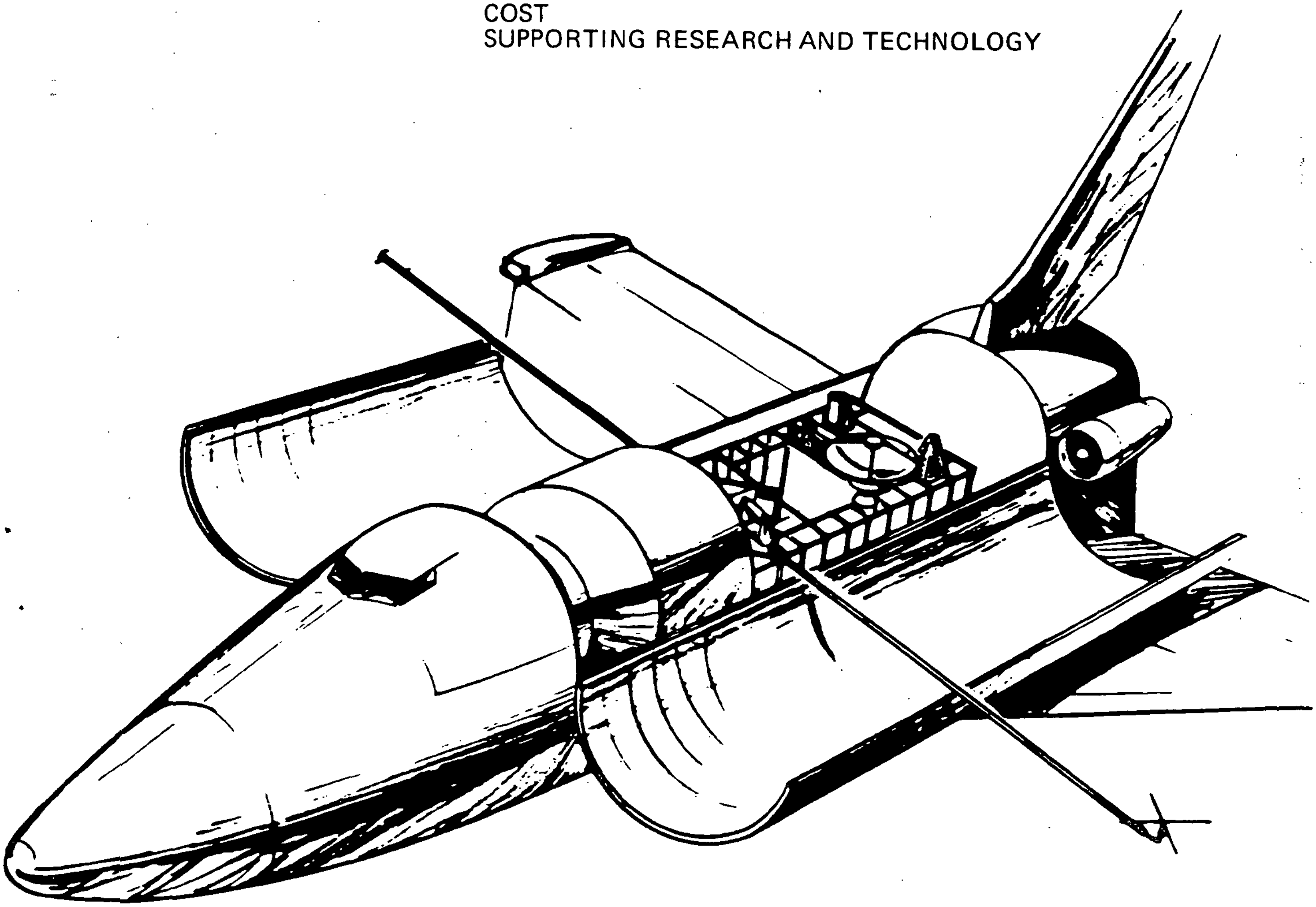
INSTITUTE FOR TELECOMMUNICATION SCIENCES

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY

COMMUNICATIONS SATELLITE CORPORATION

THE STUDY REPORT CONSISTS OF FOUR VOLUMES AS FOLLOWS

VOLUME I - EXECUTIVE SUMMARY
VOLUME II - EXPERIMENT SELECTION
APPENDIX - EXPERIMENT DESCRIPTIONS
VOLUME III - LABORATORY DESCRIPTIONS
VOLUME IV - PROGRAMMATICS
- DEVELOPMENT SCHEDULE
- COST
- SUPPORTING RESEARCH AND TECHNOLOGY



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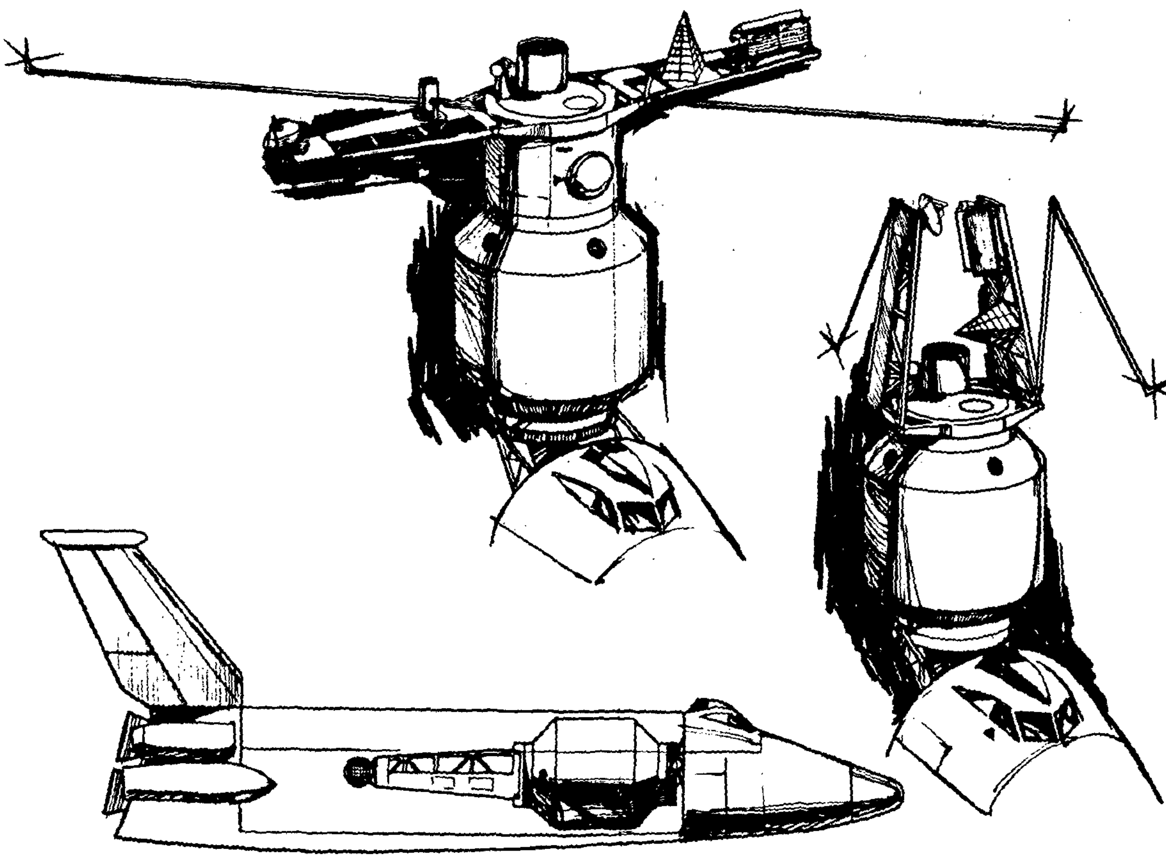

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SECTION 1

INTRODUCTION

Volume IV, Programmatics, is part of a four volume Study Report on a Phase A Study for NASA Marshall Space Flight Center entitled: "Definition of Experiments and Instruments for a Communication/Navigation Research Laboratory." The purpose of the study is to develop conceptual designs for a Space Shuttle supported manned research laboratory capable of conducting various selected experiments in the fields of communication and navigation.

Volume I is an Executive Summary. Volume II describes the candidate experiment program selection process and provides writeups on the 18 Experiment Classes encompassing the Comm/Nav space research program. Volume III covers major laboratory equipment, systems and operations analysis in support of the laboratory designs, and conceptual layouts of the Comm/Nav Research Laboratory.

Volume IV, under this cover, depicts schedules, costs, and SRT requirements for the laboratory equipment and instrumentation.

A summary of the candidate Comm/Nav experiments program and its time phasing derived during Task 1 of this study is given in Section 2. Also presented in Section 2 are photographs of the 1/20 scale model of the Shuttle supported Early Comm/Nav Research Lab showing both the baseline, in bay, arrangement and the out-of-bay configuration. These configurations represent work of Tasks 4 and 5.

Section 3 contains the postulated schedule of milestones for the Early, Growth, and Total Comm/Nav Research Laboratories; and discusses a possible flow of operations for the Early Lab missions.

In Section 4, cost estimates are presented by DDT&E design, development, test and evaluation) and Production for the Experiment Unique, Common Core and Controls/Displays equipments, for each of the seven (7) experiment classes assigned to the Early Laboratory. The equipment/instrumentation derivation was the result of work in Task 2 and 3.

Section 5 defines 20 Supporting Research and Technology (SRT) requirements that are deemed pertinent to development of the 18 Comm/Nav experiment classes.

The study concentrated on definition of the Early Comm/Nav Research Lab as opposed to giving equal treatment to the Early, Growth, and Total Labs. Consequently the costs and development schedules in this volume, which relates to study Task 6, presents data on only the Early Lab experiment equipment/instrumentation.

Summary information on the three types of Comm/Nav Research Labs is given on Table 1-1. Programmatic highlights are listed below.

EARLY COMM/NAV RESEARCH LAB
PROGRAMMATICS HIGHLIGHTS

- Seven Experiment Classes accommodated on Sortie Lab/Pallet.
- Three to four years estimated for development and production of Early Lab experiment equipment.
- Four to twelve months estimated for integration of the Early Lab experiment equipment into the Sortie Lab for dedicated Comm/Nav research missions on 7-day Shuttle Orbiter flights.
- Early Comm/Nav Research Lab, Sortie Lab, missions start in 1979 or 1980; however equipment is so defined that Comm/Nav experiments can fly as individual experiments on prior flight opportunities.
- Experiment Unique Equipment estimated at \$25.44M, Common Core Equipment at \$3.99M and Controls/Displays at \$13.95M.
- A savings of \$5.06M results from use of Common Core equipment versus each Experiment Class furnishing all its needed equipment.
- Commercial equipment modified for manned space labs can be a favorable economic factor.
- Significant savings could result in expense of the highest cost Experi-Class, Laser Communication, if related hardware development activity by other Government agencies is utilized.
- Twenty items of SR&T identified for the total Comm/Nav research program - 18 Experiment Classes.

Table 1-1. Comm/Nav Research Laboratory Summary Design and Operations Information

	EARLY LABORATORY	GROWTH LABORATORY	TOTAL LABORATORY
Time Period for Orbit Operations	1980 - 1985	1985 - 1990	1990 →
Launch and Earth Return	Shuttle Orbiter	Shuttle Orbiter	Shuttle Orbiter
Support On Orbit	Shuttle Orbiter	Shuttle Orbiter or Space Station	Shuttle Orbiter or Space Station
Crew Size	2 experimenter crew	2 to 4 experimenter crew	Up to 6 experimenter crew
Mission Duration for Lab	7 day Sortie	1 month to 1 year	2 to 10 years
Experiment Classes Accommodated	4 to 7	Up to 12	All 18
Lab Interfaces with Shuttle	Minimum	Moderate	Extensive
Lab Estimated Weight	17,000 to 20,000 pounds	20,000 to 25,000 pounds	25,000 to 60,000 pounds
Subsystems	Developed, off the shelf	Early Lab subsystems with update	Space Station subsystems
Automation	Minimum	Increased automated events	Highly automated
EVA	None scheduled	Some EVA	Scheduled EVA
Commercial Equipment Modified for Space	Some	Increased use	Significant amount
Maintenance	None planned	Some scheduled	Routine maintenance/repair
On-board Data Processing	Some	Increased use	Extensive use
Configuration Description	MSFC Sortie Lab. Pressurized module plus pallet. Operated in Orbiter bay is the baseline, but could rotate 90° out of bay for better performance.	MSFC Sortie Lab extended and improved. Could also be unmanned/free-flying from Orbiter or Space Station. Growth lab could include a family of host vehicles.	Large pressurized module attached Space Station. Complete research facility in space.
Orbit Performance	Alt. and incl. tied to Shuttle Orbiter limitations. Alt. range 100 to 470 nautical miles. Incl. 0° to 90°.	Shuttle attached labs are tied to Shuttle limitations. Free-flyers could go to geosynchronous altitude via Tug.	Alt. and incl. tied to Space Station limitation. Nominal orbit is 270 nautical miles, altitude at 50° incl.

SECTION 2

EXPERIMENT CLASSES AND LABORATORY CONFIGURATIONS

The Communication/Navigation experiment classes, described in Volume II, and the laboratory configurations to accommodate the experiment classes, depicted in Volume III, are summarized in this Section.

2.1 Experiment Class Identification

Using criteria related to usefulness, timeliness, cost effectiveness, experiment duration, orbital considerations, compatibility with the NASA automated spaceflight program, and role of the experimenter crew, experiments were solicited from a wide cross section of scientific community and Comm/Nav user agencies. The collected experiments were then screened, combined, and grouped into 18 Experiment Classes. A catalogue of these 18 experiment classes look like this:

Measurements Related to Natural Environment

Radio Frequency Interference (RFI)

Experiment Class 1 - Terrestrial Sources of Noise and Interference
Experiment Class 2 - Susceptibility of Terrestrial Systems to Satellite Radiations

Propagation

Experiment Class 3 - Radio Frequency
Experiment Class 4 - Optical Frequency
Experiment Class 5 - Plasma (Re-entry)

Measurements Related to Demonstration and Test of Comm/Nav Hardware

Communications Techniques and Services

Experiment Class 6 - Direct Broadcast
Experiment Class 7 - Communication Relay Tests
Experiment Class 8 - On-board Data Processing
Experiment Class 9 - Laser CommExperiments
Experiment Class 10 - ELF/VLF
Experiment Class 11 - Fixed Multibeam
Experiment Class 12 - Large Reflector Deployment
Experiment Class 13 - Narrow Beam Tracking

Navigation Methods and Demonstrations

Experiment Class 14 - R and $\dot{R}$ Nav and Surveillance Techniques
Experiment Class 15 - Interferometric Nav and Surveillance Techniques
Experiment Class 16 - Landmark Tracking
Experiment Class 17 - Laser Ranging
Experiment Class 18 - Horizon Altitude and Radiance Profile Measurement

2.2 Experiment Class Time Phasing

The 18 Experiment Classes were subjected to analysis for priority rating and assignment to Early, Growth, and Total Laboratory flights. Results of this exercise indicated that, for purposes of laboratory configuration design, equipment layout, mission planning, and laboratory instrumentation cost estimates, the following could be representative of Experiment Class placement.

Early Lab Experiment Classes (1980-1985)	Growth Lab Experiment Classes (1985-1990)	Total Lab Experiment Classes (1990→)
1	Early Lab Experiment	Early and Growth
3	Classes Plus	Experiment Classes
7	2	Plus
9	5	4
11	8	6
15	13	10
16	14	12
	18	17

Clearly, the above suggested experiment program should be periodically reviewed to insure that it complements unmanned spaceflight experiments, is cost effective for implementation, and is tuned and time-phased to technological gaps.

2.3 Early Laboratory Concepts

An initial Communications/Navigation Research Laboratory is contemplated as a Space Shuttle Orbiter supported, general purpose, reusable, laboratory that could accommodate a wide variety of measurements for the seven Comm/Nav Experiment Classes assigned to it and also be flexible enough to permit exchanges of Experiment Classes should program priorities dictate.

Considering equipment weight, volume, needed services requ ments and also taking into account the two-man experimenter crew tin available on a seven-day Sortie mission for experiment related activit an Early Laboratory baseline configuration is shown in Figure 2-1.

Figure 2-1 is a photograph of a 1/20 scale model of a Comm/ Research Lab operating in the cargo bay of the Space Shuttle Orbiter. Laboratory features a pressurized 25 ft. long x 14 ft. diameter pressu module to house the 2-man experimenter crew and equipment and a 30 long module attached pallet on which experiment antenna and optical sy are mounted.

In recognition of potential antenna RF blockage, thermal contr and waveguide length-of-run problems which could be associated with tl in-bay configuration of Figure 2-1, an alternate design approach was studied.

Figure 2-2 shows an out-of-bay Comm/Nav Research Lab as tl alternate. The 25 ft. long x 14 ft. diameter pressurized module end do ring was modified to accept a double 16 ft. long boom structure. After 90 degree rotation of the pressurized module out of the Orbiter bay, the antenna boom is deployed. Each 16 ft. arm is placed normal to the Shuttle longitundinal axis. Total antenna boom arm deployed is then 32 feet. The same antenna and optical systems placed on the pallet in the in-bay baseline configuration of Figure 2-1 are shown arranged on the 32 ft. boom of Figure 2-2.

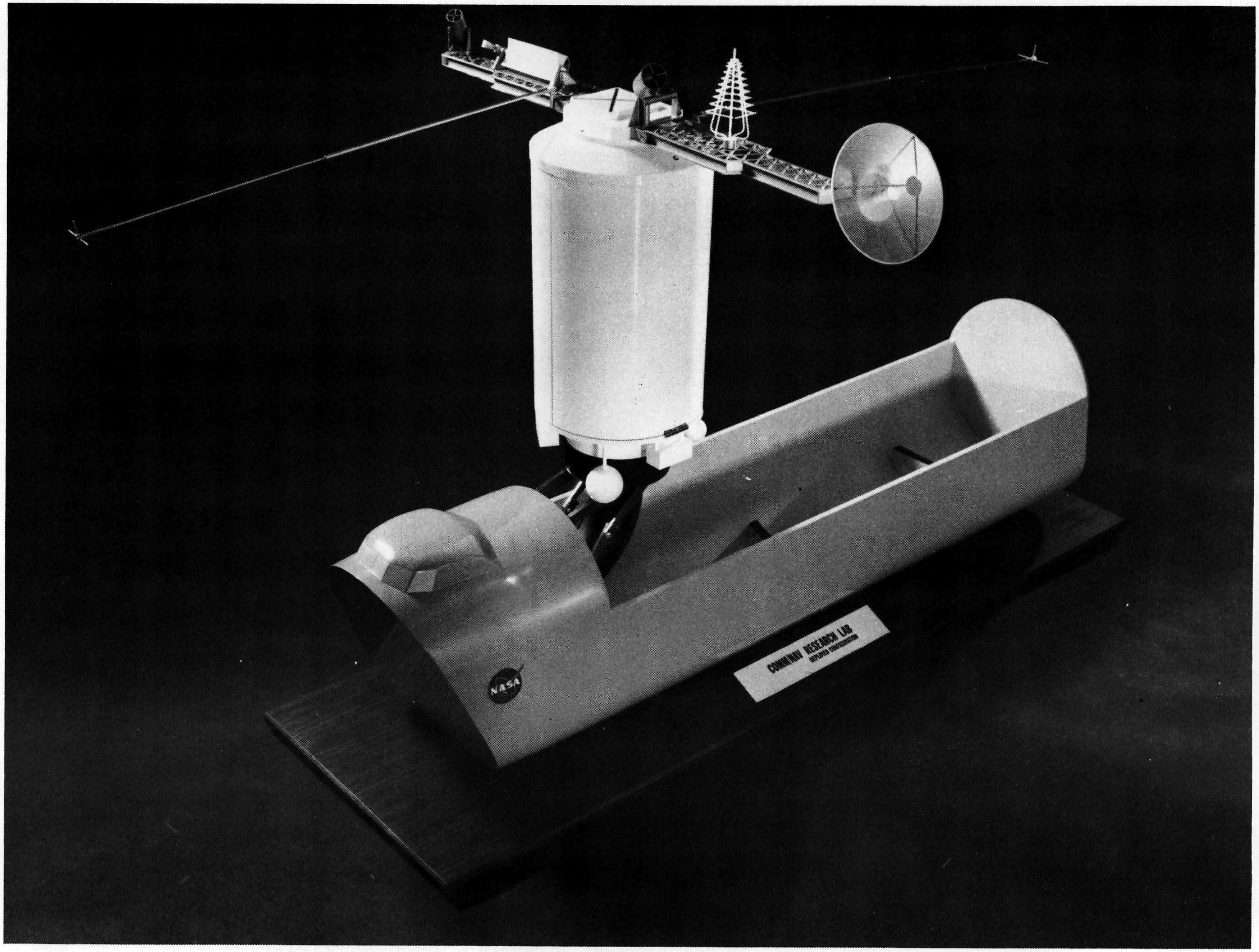


Figure 2-2. Comm/Nav Research Lab, Out of Shuttle Orbiter Bay Configuration. Photograph of a 1/20 Scale Model

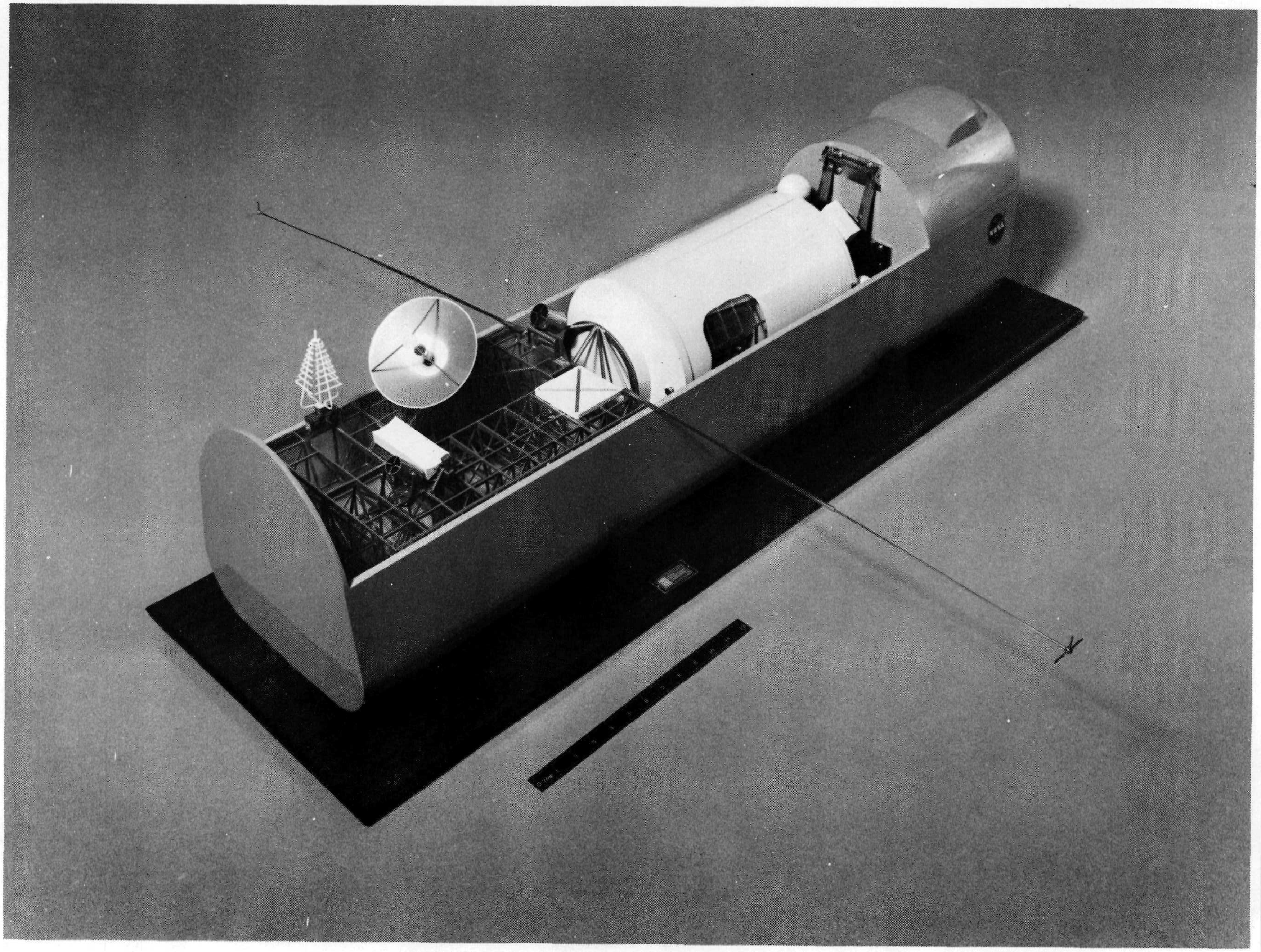


Figure 2-1. Comm/Nav Research Lab, In Shuttle Orbiter Bay Configuration. Photograph of a 1/20 Scale Model

SECTION 3

DEVELOPMENT SCHEDULES

This section defines the time phased milestones and calendar relationships important to the development of the NASA program of Comm/Nav space experimentation in manned research laboratories.

3.1 Development Guidelines

The following schedule guidelines were followed during the study Task 6 work pertaining to development of Comm/Nav Research Laboratories:

1) Initial operational capability of the Early Comm/Nav Research Laboratory in 1979 or 1980.

2) Launch to orbit, on-orbit support or service, and return to Earth is by the Space Shuttle. Future option Growth and Total Laboratories may utilize the Space Station for some aspects of support.

3) Maximum use should be made of existing support and common core hardware to minimize development time and costs.

3.2 Comm/Nav Experiment Program

NASA's objectives, derived from the Space Act of 1958 and the Communications Satellite Act of 1962, can be summarized as........ "To facilitate the application of satellite systems and space technology to national and international communication service needs and to the improvement of terrestrial, air, and space vehicle navigation and traffic control."*

To satisfy these objectives, NASA conducts or sponsors a sequence of activities that includes the investigation of the needs for new communication or navigation services and the assessment of space technology to meet the needs or fill the technology gaps. The elements contributing to the development of operational space systems to meet the requirements

*Communications Program Review, Issued by the NASA Headquarters Office of Space Science and Applications, January 1970.

associated with new service objectives includes the items shown on Figure 3-1. Manned Comm/Nav Orbital Research Labs may make a significant contribution to the total program of activities leading to future operational Comm/Nav space systems.

3.3 Comm/Nav Research Laboratories Schedule

The study examined three versions of the Comm/Nav Research Laboratory — Early Lab, Growth Evolutions of the Early Lab, and the Total Lab. Experiment classes were derived, Study Report Volume II, and assigned for flight implementation to the three laboratories. Arbitrary dates were selected for start of Comm/Nav flights with the three laboratories. Figure 3-2 depicts the study derived schedule of milestone events postulated for the three laboratories. The Comm/Nav Research Laboratory concept is an integral part of the total NASA Comm/Nav program. The concept should be planned to complement the ground based, aircraft/balloon, and unmanned spacecraft research and development activities.

Not specifically indicated on Figure 3-2 is the idea that with concurrent development of laboratory experiment equipment with aircraft and unmanned flight lies the possibility of flying portions or logical assemblies of the experiment equipment on various flight opportunities that might arise prior to Shuttle Laboratory missions.

3.4 Early Comm/Nav Research Laboratory Development Schedule Details

The Early Laboratory schedule shown on Figure 3-2 is presented in a more detailed summary of events and milestones on Figure 3-3. This schedule plan is directed at a Sortie Lab dedicated to Comm/Nav research with missions to conduct Comm/Nav experiments starting in 1980. Thus, the 1980 Sortie Lab ready for Comm/Nav experiment equipment is the host vehicle — and called the Early Comm/Nav Research Laboratory.

NASA may fly an austere Sortie Lab on the Space Shuttle development flights in the 1978-1979 period. Space Shuttle operational flights are presently scheduled for late-1979 or early-1980's. Certain Comm/Nav experiment class equipment could be available for these austere (maybe multi-disciplined) Sortie Lab/Shuttle development missions in

1978-1979. Other pre-1980 manned or unmanned spacecraft missions may also provide flight opportunities to develop hardware or techniques. Of the seven experiment classes assigned to the Early Comm/Nav Research Laboratory, possibly the equipment for experiment classes of RF Noise Interference, Propagation, and Multibeam Antenna could be flown on 1978-1979 austere Sortie Lab missions. Thus, the key issue of some early applied benefits could be realized.

The schedule of Figure 3-3 shows the need to pace the Early Laboratory experiment hardware development/fabrication to the development/fabrication of the host vehicle — the Sortie Lab. Additional details of the Sortie Lab development/flight schedule of activities is given in Section 2 of the document titled Sortie Lab System Utilization Characteristics, June 27, 1972, by the Program Development Preliminary Design Office of NASA MSFC.

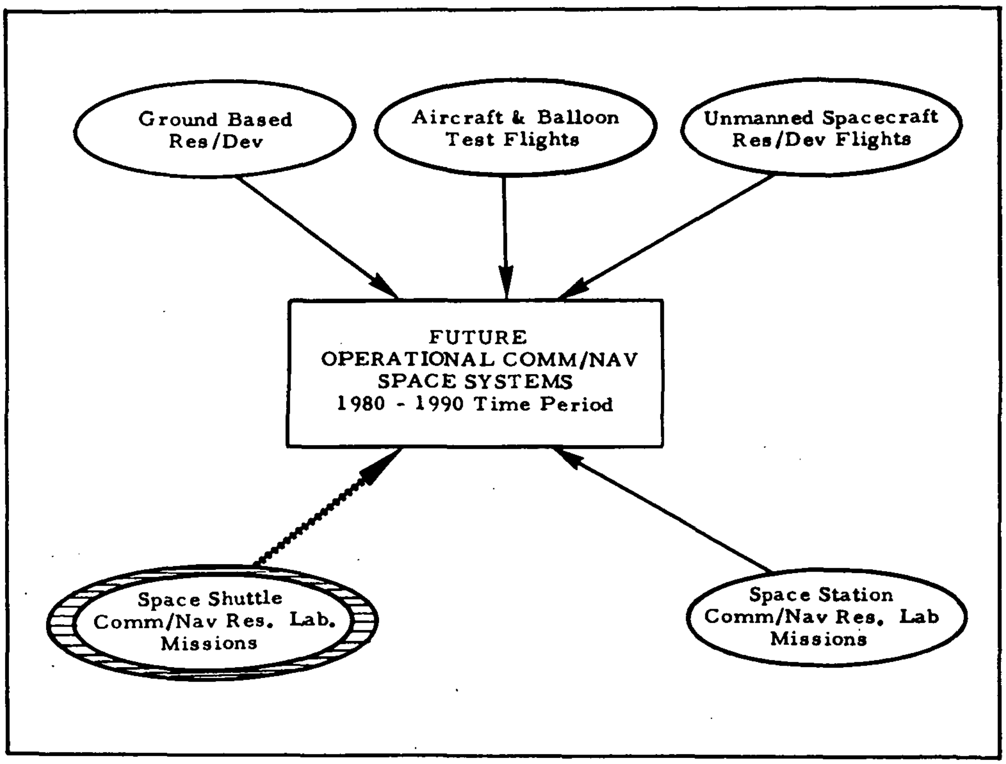


Figure 3-1. The Comm/Nav Research Lab Experiment Program of Shuttle Supported Space Missions Will Contribute to Providing Solutions to the Technology Gaps Which May be Associated with Future Operational Comm/Nav Satellite Systems

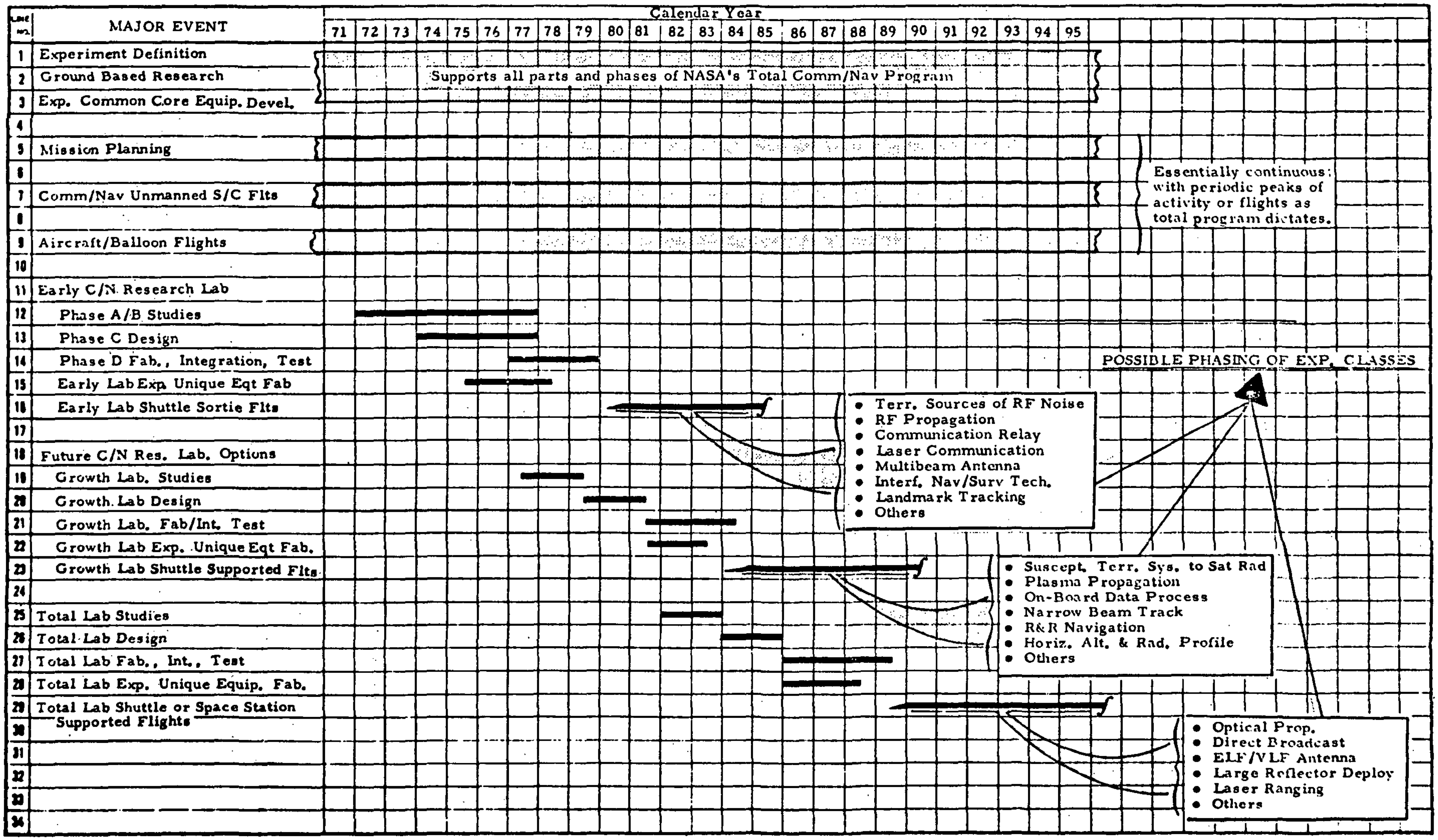


Figure 3-2. Postulated Schedule of Milestones Relative to Time Phasing of Events for Early, Growth, and Total Comm/Nav Research Laboratory

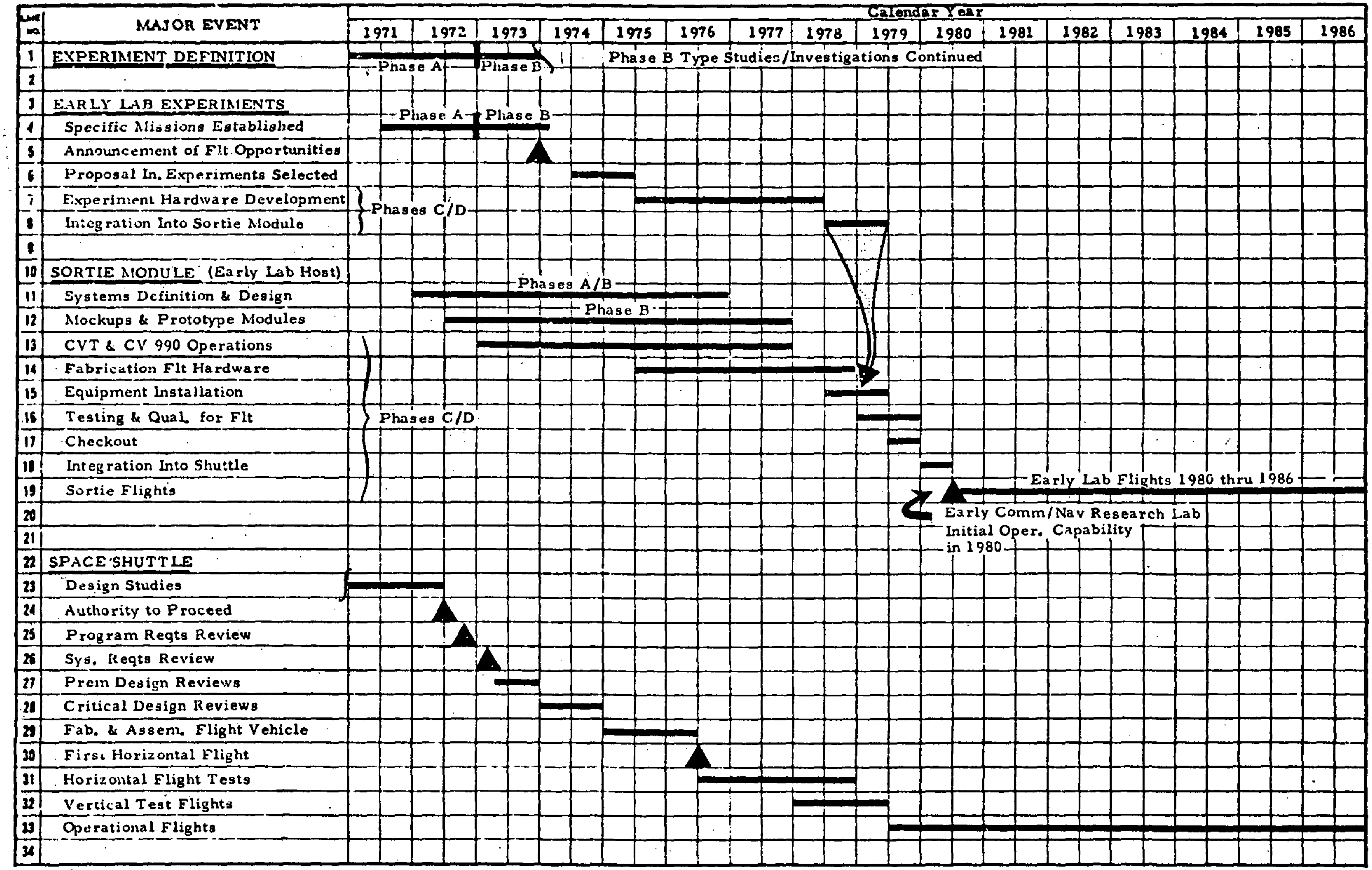


Figure 3-3. Hypothetical Master Schedule for Development and Flights of Early Comm/Nav Research Laboratory

3.5 Early Laboratory Event Flow

A model operational flow concept of Comm/Nav Research Laboratory events is shown in Figure 3-4. The overall objective of the model concept depicted by the chart is to simplify and shorten the process of Comm/Nav space experimentation and to reduce its cost. Another important aspect of the model concept is to provide the opportunity for direct participation by Comm/Nav experiment investigators in either the flight operations or data analysis. An additional important item shown is the possible mix of NASA and contractor participation in the various operations.

The model envisions a NASA Shuttle Payloads Office established to serve as the focal point for the research ideas, experiment definition studies and experiment SR&T emanating from Government, industry, and university sources. Also, this Office would exercise overall management authority for Shuttle payloads (of which Comm/Nav is one).

The NASA Shuttle Payloads Office would select Comm/Nav experiments to be flown on missions against an established Shuttle missions flight plan.

A NASA Center for manned Comm/Nav experiments would be designated. This NASA Center might have responsibility for development of the Comm/Nav payload carrier (Sortie Lab), the experiment peculiar equipment, experiment common core equipment, controls and displays, and experiment support equipment.

It is assumed that the Comm/Nav carrier for Early Shuttle missions will be the MSFC Sortie Lab or some derivative thereof.

Under the direction of the NASA Center for Comm/Nav, the Sortie Lab would undergo development. This Center would also issue contracts to design, develop, test and deliver experiment unique instrumentation for the seven experiment classes presently designated for the Early Comm/Nav Laboratory. See Study Volumes II and III. For purposes of depicting operational flow, it is assumed that these seven contracts would be given to seven different contractors to produce the equipment that is unique to the experiment. Actually, in practice a contractor could receive more than one experiment contract.

Additionally, the NASA Center for Comm/Nav payloads would issue contracts for the common core, displays and controls and support equipment.

The Project Management Office and the Systems Engineering Groups at the NASA Centers for Comm/Nav payloads would be responsible for the coordination of engineering and administrative activity between the various experiment, common core, controls and displays and support equipment contractors. It is assumed, however, that each contractor would have his own internal Project Management and Systems Engineering Office to perform functions related to these items within his own contract.

At a point in time related to contract deliverable requirements and Sortie Lab development, the various items contracted for and the Sortie Lab would be delivered to a Comm/Nav Carrier/Payload Integration Site. This site might also be the place where other discipline payloads would be integrated to their carrier and, indeed, where multi-discipline payloads would be integrated with carriers. This Integration Site could or could not be physically located at the same place as the Comm/Nav NASA Center or the launch site. For purposes of this description it is assumed that the Integration Site is at a different location from the launch site, which is assumed to be NASA's KSC for Early Shuttle missions.

The Integration Site would be supported by both NASA and personnel from an integration contractor. The mix of these people is not specified in this event analysis. Certain integration hardware will either be delivered to the Integration Site under separate contracts, fabricated at the Integration Site by the integration contractor or fabricated at the Integration Site by NASA. The chart indicates the various kinds of integration hardware required. The chart also indicates the functions to be performed by the NASA/integration contractor personnel. These functions include administrative, engineering, testing, simulation and training work, as well as the physical actions of integrating the experiment equipment to the Sortie Lab Carrier.

At the Integration Site the experiment hardware should be thoroughly checked out in a high fidelity mock-up of the total Sortie Lab prior to

installation in the actual flight model Sortie Lab. Passenger/Investigator flight crew training will take place utilizing mock-up and simulation equipment.

It is estimated that four to twelve months will be required at the Integration Site to perform the functions necessary to qualify the Sortie Lab/Comm/Nav payload for shipment to the Launch Site.

After arriving at the Launch Site, it is estimated that 15 to 30 days will be required to perform the functions shown on Figure 3-4. These functions are assumed to be a NASA operation with contractor's support, as needed (and yet to be defined).

The early Comm/Nav Lab Shuttle Sortie mission is presently planned as a seven-day flight, five days of which constitute data taking. The items shown on Figure 3-4 are indicative of orbital flight operations.

At the conclusion of the seven-day mission, it is assumed that six to ten days will be required for post-flight activity. Specific items related to the post-flight activity are shown on the chart. Of specific interest at this time are the events related to the Comm/Nav data.

The data that is stored aboard the Comm/Nav Lab will be delivered to a Data Processing Facility. The real-time data transmitted to the ground during the actual flight will also be delivered to the Data Processing Facility. This Data Processing Facility could be located at some central place where data from other Shuttle payload discipline missions will be brought for processing, or it could be located at the NASA Center for Comm/Nav. One to three months time is estimated for processing the raw data into a form suitable for distribution to user agencies or principal investigators, or to the contractor who provided the experiment unique equipment, or to both, for data analysis. If the data were analyzed for each experiment separately, it would probably be the responsibility of the Project Management Office or the Systems Engineering Office at the NASA Center for Comm/Nav to provide the data analysis correlation across all seven experiments.

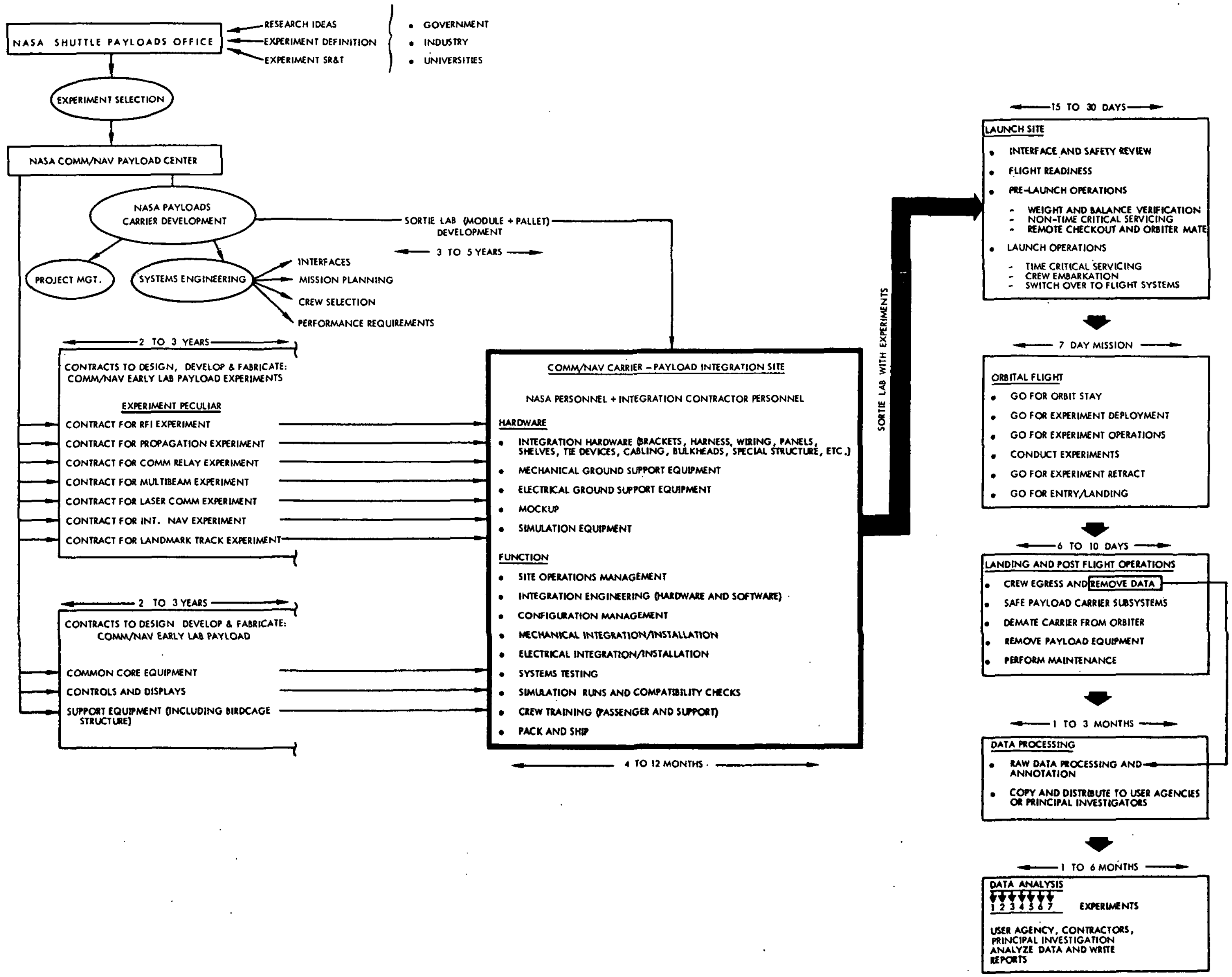


Figure 3-4. Possible Flow of Operations for the Early (Sortie Missions) Comm/Nav Research Laboratory

SECTION 4

COMM/NAV RESEARCH LABORATORY EXPERIMENT EQUIPMENT COST ESTIMATE

A continuing cost analysis of the equipment/instrumentation for the Early Comm/Nav Research Laboratory was an integral part of the study. The analytical approach to generation of costing data included the use of:

- Cost Estimating Relationships (CER's)
- Cost data banks
- Point estimates
- Inputs from manufactures of commercial equipment

The Comm/Nav Research Lab work breakdown structure provided the overall costing format for the indentification of program cost items, and as such, served as the collecting point for cost estimates expected to be incurred during the program.

4.1 Cost Analysis Assumptions and Guidelines

Listed below are the assumptions and/or guidelines that were followed in estimating the equipment and instrumentation costs for the Early Comm/Nav Research Laboratory.

1. The Early Comm/Nav Research Laboratory would be operational in 1979 or 1980 and its initial flights in low earth orbit supported by the Shuttle orbiter would perform research in the following experiment classes:

Class No.	Experiment Class Name
1	RFI — Terrestrial Sources of Noise and Interference
3	Propagation — Radio Frequency
7	Communications Systems — Communication Relay Tests
9	Communications Systems — Laser Comm. Experiments
11	Communications Antennas — Fixed Multibeam
15	Navigation Systems — Interferometric Nav and Surveillance Techniques
16	Navigation Aids — Landmark Tracking

2. The host vehicle laboratory, Sortie Lab, which houses and supports the Comm/Nav experiment equipment and instruments is assumed to be GFE. The Sortie Lab consists of a pressurized module with subsystems plus an attached tubular structured pallet as defined in Volume III.

3. This study concentrates on the DDT&E (non-recurring) and the one-flight production (recurring) costs of the hardware associated with the seven Early Laboratory experiment classes, with no provision for spares or operations refurbishment costs.

4. Cost estimates developed in agreement with the work breakdown structure and stated in Government fiscal year 1972 dollars.

5. No learning curve has been assumed.

6. Costs assume commonality as a primary consideration; that the same prime contractor will have responsibility for designing and producing all the experiment equipment; that the same designs of one mission will be employed to the maximum extent possible for succeeding missions; and that there will be no technology increases during the program. Also, the initial design employs maximum use of existing equipment.

7. Costs are based upon TRW Systems historical cost estimating relationships and similar cost data from McDonnell Douglas Astronautics Company.

8. The estimating methodology is generally applicable to low quantity and low production rate manned spacecraft, and cost improvement due to learning is not included for hardware at Level 5 or above.

9. All G&A and other overheads and burdens are included in each of the individual cost elements reported.

10. No costs are included for NASA technical or administrative support.

11. No costs are included for operations support, Sortie Lab integration, or specialized ground facilities or system tests, or mockups.

12. Project Management and System Engineering are based on one contractor developing the seven Experiments, related Common Core, and Controls and Displays.

4.2 Costing Methodology

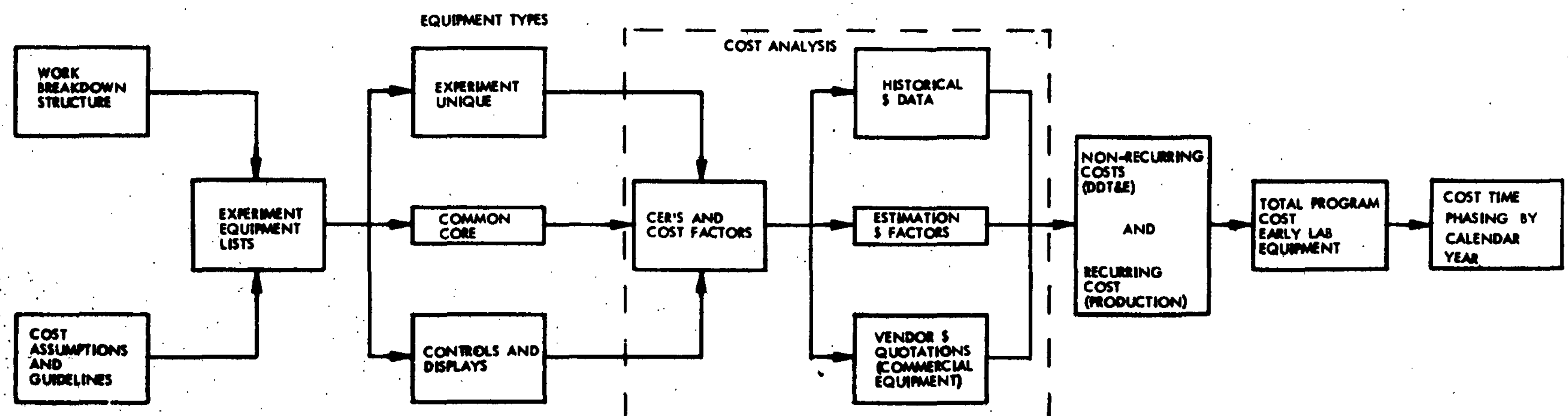
The approach used to generating Early Comm/Nav Research Lab experiment equipment costs is depicted in the flow diagram below. The Work Breakdown Structure (discussed in 4.3) provided the overall cost format and was used as a basis for all cost inputs. The WBS also set the requirements for cost estimating relationships (CER's), cost factors and point estimates. The CER's were derived on the basis of analysis and from TRW and McDonnell Douglas historical cost data sources.

Lists of experiment unique, common core and control/display equipment/instrumentation for Early Lab experiments served as the starting point for cost estimates. The Sortie Lab (Module plus Pallet) with its subsystems and basic furnishings was considered to be NASA supplied.

Estimates or cost factors were derived for each of the laboratory equipment cost elements. A survey and a collection of available cost and technical data was made from available sources including historical hardware programs, study programs, and other detailed estimates. The data obtained were subjected to a thorough analysis to determine validity and confidence level, and normalized to the ground rules to provide for varying raw data inclusions and exclusions. This data was then analyzed to establish technological families (groupings based on hardware type, complexity, and state of the art) and to select an appropriate parameter (performance or sizing) that shows good correlation with cost for use in cost prediction. Valid high confidence data-point families resulting from this analysis were used to derive the cost relationships.

The high degree of commonality and off-the-shelf commercial equipment items necessitated the use of a development factor for the appropriate adjustment of the CER's to obtain a proper relation to the historical data from which it was derived. The factor included 1) an assessment of design complexity, 2) a commonality factor to establish the previous applicable development, and 3) the degree of new development required, which relates to component availability (off-the-shelf, etc.). Recurring production hardware CER's also required a complexity factor to provide for a proper relation to available historical data.

Point estimates used in the cost estimate in many cases were generally estimated in greater detail. These were estimated by either a detailed approach or a more summary method, including comparative techniques with current ongoing hardware or study programs, analysis of historical costs, and commercial vendor quotes.



Cost Analysis Flow

4.3 Work Breakdown Structure (WBS) and Dictionary

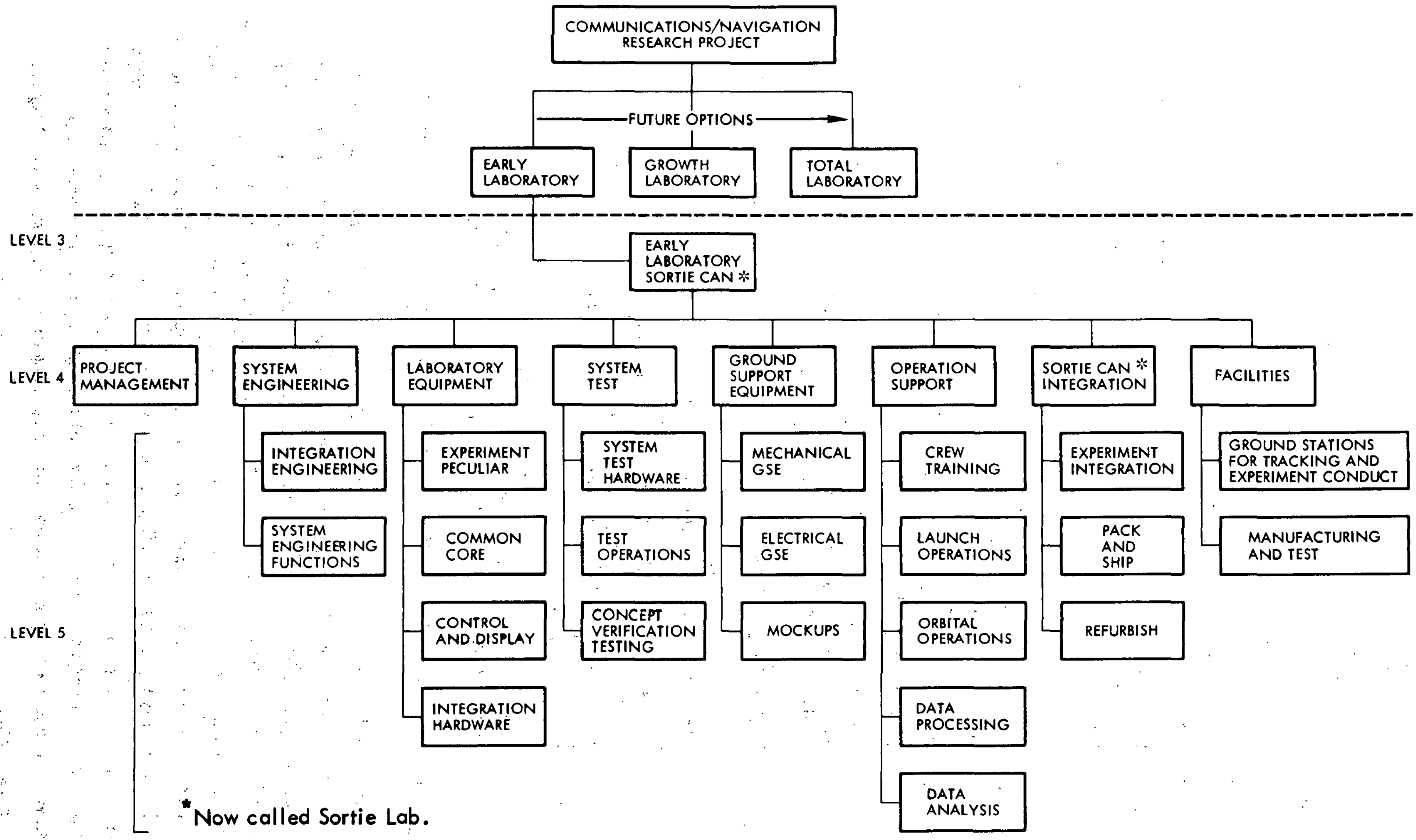
The WBS reflects the principal categories of hardware, services, and other tasks comprising the Comm/Nav Research Laboratory (CNRL) project, and is shown in Figure 4-1. It displays, in an end-item structured breakdown, functional units of work, Level 4, that form an organizational framework for implementation, management, and control of hardware development, schedule plans and status, and cost accumulation. The WBS units of work are subdivided into manageable elements, Level 5, for which there are technical definition and for which schedules and resource application estimates can be prepared and monitored in reportable packages.

The definitions to follow were developed for all WBS elements through Level 5 of Figure 4-1. Since this study concentrated on the Early Lab, only the Early Lab Level 4/5 WBS elements were developed. For purpose of structuring the work breakdown and for costing the elements, it was assumed that all equipment for the seven Early Lab selected experiments would be produced by NASA under one contract.

Communications/Navigation Research Project — All elements of a manned host laboratory/experiment equipment system capable of supporting a wide variety of experiments in the disciplines of communications and navigation in near earth orbit Space Shuttle/Station flights.

Early Laboratory — CNRL host vehicle is the Sortie Can (or Sortie Lab as it is now called).

- Launch and earth return by Space Shuttle
- Space Shuttle Orbiter supported
- Minimum Space Shuttle interface
- Fail safe design criteria
- Laboratory removable from Space Shuttle Orbiter bay for ground operations
- Experiment pallet detachable from laboratory
- 1980 - 1985 time period
- Seven-day Sortie missions
- Two experimenter crew
- Accommodate seven experiment classes
- Off-shelf subsystems
- Minimum automation
- No scheduled EVA
- Some commercial equipment
- No planned maintenance
- Some on-board data processing.



*Now called Sortie Lab.

Figure 4-1. Communications/Navigation Research Laboratory Work Breakdown Structure

Growth Laboratory — CNRL host vehicle not yet specified by NASA.

- 1985 - 1990 time period
- One month to one year mission duration
- Two to four experimenter crew
- Growth Laboratory is Shuttle Orbiter supported or serviced
- Laboratory accommodates up to 12 experimenter classes
- New experiment complement
- Extension of Early Laboratory experience
- Precursor to Total Laboratory
- Free-flyer capability
- Improved geographic coverage
- Extended mission time on orbit
- Exploit/evaluate EVA capability
- Deliver automated spacecraft (subsatellites) to orbit for advanced cooperative experiments
- Early Lab subsystems with component update
- Increased automated events
- Some EVA
- Increased commercial equipment
- Some scheduled maintenance
- Increased on-board data processing and analysis.

Total Laboratory — CNRL host vehicle, not yet specified by NASA.

- 1990 ⟶ time period
- Two to ten year mission duration
- Six experimenter crew
- Delivered to orbit by Shuttle Orbiter, then attached to the Space Station during the mission, resupplied by Shuttle
- All (18) experiment classes accommodated
- Highly automated
- Scheduled EVA
- Significant use of commercial equipment
- Routine maintenance and repair. Fault isolation
- Extensive on-board data processing and analysis.

Level 3 Early Laboratory Sortie Lab): (other terms are Sortie Module, Sortie Can):

A manned laboratory suitable for conducting research and applications activities on Shuttle sortie missions transported to and from orbit in the Shuttle payload bay and attached to the Shuttle orbiter stage throughout its mission. The Sortie Lab will be characterized by low cost versatile laboratory facilities, rapid user access, and minimum interference with the Shuttle orbiter turn-around activities. Unless specifically stated, the Sortie Lab includes an attached unpressurized instrument platform called a pallet. A pallet is an unpressurized platform for mounting telescopes, antennae and other instruments and equipment requiring direct space exposure for conducting research and applications activities on Shuttle sortie missions.

A pallet will normally be attached to a Sortie Lab with the pallet experiments being remotely operated from the Sortie Lab. A pallet can also be attached directly to the Shuttle orbiter and operated from the orbiter cabin.

Level 4 Project Management

This element sums the effort required to provide direction and control of the development and operation of the Early Lab experiment equipment. These efforts are required for planning, organizing, directing, coordinating, and controlling the project to insure that overall project objectives are accomplished. These efforts overlay the other functional categories and assure that they are properly integrated. This element also includes the efforts required in the coordination and in gathering and disseminating information to the customer and associate contractor personnel.

Level 4 System Engineering

This element includes all system engineering effort required to define and allocate engineering requirements necessary to direct and control an integrated approach to design, development, and operations, and all the effort required to plan and implement those activities necessary to insure a quality, reliable, and maintainable product. It includes system analysis of performance and operational requirements, special studies and trade studies, system cost effectiveness evaluation, and interface requirements definition. Design reviews and technical performance measurement are also included in this element.

Level 4 Laboratory Equipment

This element sums all the engineering and production effort and hardware necessary to outfit the CNRL with the experiment related equipment and instruments. Included are: those items of hardware uniquely related to one experiment class of research, hardware common to two or more research classes, devices associated with the control/display function in the Sortie Lab, and the hardware needed to install the laboratory experiment equipment into the Sortie Lab host vehicle.

Level 4 System Test

This element includes all the effort, materials, hardware and services required to perform all system level test operations on experiment

class equipment. The tests may be both independent of or in conjunction with CNRL host vehicle testing.

Level 4 Ground Support Equipment

This element refers to all effort, material, and hardware needed to define, design, assemble, checkout, and deliver mechanical and electrical ground support equipment and also the mockups required for CVT, crew training, and mission monitoring during actual orbital operations. Uses of the GSE and mockups are covered in other WBS elements. All GSE costs are considered only DDT&E (non-recurring) since the GSE produced under DDT&E would be the same equipment used in support of the experiment flight (production) equipment.

Level 4 Operations Support

All crew training actions, mission conduct efforts, and data processing/analysis events are included in this element. It covers the time period from acceptance of the CNRL through the lifetime of the laboratory and the time need for data processing and analysis.

Level 4 Sortie Lab Integration

This element includes all the effort and material and hardware needed to physically integrate the experiment equipment into the Sortie Lab, and after test and checkout events, pack in ship the integrated Sortie Lab to the Launch site. It also includes all between missions refurbishment and maintenance functions that are planned as the overall concept for conduct of the CNRL project.

Level 4 Facilities

This element sums all the effort, material, and equipment required for facilities to conduct CNRL flights. Implicit here is the assumption that special ground facilities may be needed to properly conduct some of the experiments or measurements specified in the Comm/Nav flight research program and new facilities or modifications to existing facilities may be required.

Elements of work at Level 5 are summarized below:

Level 5 Project Management (Cost data provided)

This element includes:

- Planning and control (technical and financial
- Configuration management
- Production and procurement management
- Test operations management
- Quality assurance management
- Logistic support management
- Specification preparation and control
- Contract and documentation management
- Schedule control--master and supporting
- Conduct design reviews.

Level 5 System Engineering (Cost data provided)

This element includes:

Integration Engineering: (Cost data provided)
- Payload/Sortie Lab interfaces and compatibility rational
- Sortie Lab/Ground Operations interface
- Establish installation tolerances
- Mission-to-mission equipment changes
- Support test, checkout events
- Mass properties control
- Establish overall Interface Control Document
- Host vehicle evaluation.

Systems Engineering Functions
- Requirements analysis, allocation
- System performance definition
- Cost effectiveness evaluation
- Interface control
- Experiment equipment layout in Sortie Lab
- Reliability plans
- Maintainability plans
- Safety
- Human factors
- Value engineering
- Support fabrication and assembly
- Quality Assurance plans.

Level 5 Laboratory Equipment

This element includes:

Experiment Unique Equipment (Cost data provided)

An item of equipment associated with or utilized by only one experiment in a given payload complement is categorized as an "experiment-

peculiar" unit. In general this group is comprised of the specialized equipment required to implement a given experiment; however, selected commercial instrumentation may also be included where its application is restricted to a single experiment.

Common Core Equipment (Cost data provided)

The "common-core" designation identifies those items of equipment in a specified payload characterized by performance requirements which enable them to be shared by multiple experiments. Typically this group contains general purpose instrumentation (e.g., tape recorders, spectrum analyzers, general purpose computers, voltmeters, and frequency counters) which are procured from commercial vendors.

Control and Display Equipment (Cost data provided)

Those items of equipment required to perform control and monitoring functions in support of individual or collective experiments are consolidated into a "controls and displays" category. It includes power distribution, data recording, and computer capabilities.

Integration Hardware (Cost data provided)

The integration hardware is that flight-hardware/software which is necessary to assemble the experiment unique, common core and control and display equipment into an assembly that is capable of achieving experiment class objectives in the CNRL. This hardware includes birdcage structure racks, supports, cables, tie together devices, electrical harness, special end domes, antenna mounts, etc.

Level 5 System Test

This element includes:

System Test Hardware

- Dynamic/static structural and thermal models and assembly/component test articles.
- Instrumentation and test fixtures
- Test articles and spares
- GSE used in system tests
- Simulation and environmental duplication devices
- Functional models (various scales).

Test Operations

- System test model plan
- Test conduct
- Test data reduction
- Test data evaluation and reporting.

Experiment/Sortie Lab integration not included in this element.

Concept Verification Testing

- Mission simulation
- Equipment performance analysis
- Check on equipment layout/arrangement in CNRL
- Human factors analysis.

Level 5 Ground Support Equipment

This element includes:

Mechanical and Electrical GSE (Cost data provided)

- Hardware for handling, transport, and test support of experiment equipment
- Hardware for servicing, checkout and maintenance of experiment equipment
- Hardware to support launch and installation of any special experiment orientated equipment.

Mockups

- Full scale and scale mockups of experiment equipment/ instrumentation for use in integration, CVT, and crew training work
- Full scale mockups of control and display panels for use in integration, CVT, and crew training work.

Above to be hard or soft mockups, depending on the applications.

Level 5 Operational Support

This element includes:

Crew Training

- Documentation and manuals on experiment equipment and controls/displays operation. Procedures. Orbital Operations handbook
- Simulation drills in conjunction with CVT and mission planning events.

Launch Operations

- Site activation
- Launch GSE installation and maintenance
- Join Sortie Lab to Shuttle, interface check with Shuttle
- Pad checkout of experiment equipment/instruments
- Countdown, launch, ascent monitor of equipment/instruments
- Post-launch deactivation.

Orbital Operations

- Mission analysis and planning
- Update time lines
- Flight operations support to monitor experiment data and advise any changes to flight plan for experiment conduct
- Real time evaluation of priorities
- Real time quick-look check of experiment equipment functions
- Monitor experiment progress and status. Resolve mission encountered anomalies and mission in-process replanning
- Coordination with data user agencies--real time data evaluation
- Logistic liaison with launch and mission control sites for "next flight" replenishment of expendable supplies and equipment.

Data Processing

Decoding, normalization, rectification, indexing, and storage of on-board recorded and telemetry data.

Data Analysis

- Information extraction
- Comparative analysis
- Reports, documentation, maps

Level 5 Sortie Lab Integration

This element includes:

Experiment Integration

- Experiment interface requirements
- Experiment equipment reception, acceptance and storage
- Experiment interface hardware
- Experiment interface software

- Experiment interface testing
- Experiment installation in Sortie Lab and removal

Pack and Ship

- Packing/shipping containers
- Packing operations
- Transport operations

Refurbish Between Sortie Missions

- Remove and replace components and instrumentation
- Recalibration of instrumentation, scopes, and displays
- Maintenance and servicing normally accomplished at the launch/flight operations site as a result of discrepancies determined/disclosed through inspection, test, and verification activity. This may include fabrication type tasks such as structural repair, preservation and refinishing that are within the capabilities existing at the launch/flight operations site.

Level 5 Facilities

This element includes:

Ground Stations for Tracking and Experiment Conduct

- Design, fabrication, and implacement of new facilities for mission control, data acquisition, command transmission, Shuttle Orbiter tracking, and data processing. Many Experiment Classes (Laser Comm., Interferometric Surveillance, etc.) may require special ground transmission, reception, and tracking equipment placed at exact locations to operate in cooperation with the Comm/Nav Research Lab in orbit.
- Modification of existing facilities to perform above activities.

Manufacturing and Test

- Construction of special manufacturing, assembly, integration and test facilities for the fabrication or qualification or integration of the Sortie Lab or experiment equipment.
- Modification of existing facilities to perform above activities.

4.4 Cost Summary

Table 4-1 lists the estimated DDT&E and the production costs for laboratory equipment for the Early Comm/Nav Research Laboratory In-Bay Configuration. Project management, systems engineering, and ground support equipment costs are also shown. Costs include those activities beginning with the initiation of hardware equipment and continuing through production of the first flight systems.

The major thrust of the costing work in the study was to estimate the WBS level 4 laboratory equipment costs for the Early Lab. Four breakdowns are shown at level 5. The first is the experiment peculiar or experiment unique equipment; the second is common core equipment, the third constitutes the controls and displays; and the fourth pertains to integration hardware.

Nonrecurring or development cost consists of the one-time cost of designing, developing, testing, and evaluating an end item. Specifically, it includes development engineering and development support, test hardware, ground testing and evaluation, tooling and special test equipment, facilities and facility activation, and other program-peculiar costs not associated with production. It includes all the elements of cost (resources) such as labor (engineering, production, tooling, etc.), materials, subcontracts, general and administrative (G&A) expenses, and burden, as well as the subdivision of effort such as design, reliability analyses, safety and quality control, tooling production, etc., necessary for the development of the program.

The recurring production category includes the costs associated with the production of all flight hardware articles through acceptance of the hardware by the customer, including all costs associated with the fabrication, assembly, ground test, and checkout of flight articles, as well as associated sustaining engineering and tool sustaining and maintenance. As discussed above, this category includes all elements of cost and subdivisions of work necessary for production of these articles.

The Early Laboratory equipment/instrumentation costs for the experiment unique, common core, and controls/displays are estimated at \$25.44M; \$3.99M; and \$13.95M. To this sum of \$43.38M is added the costs for GSE, \$6.54M; integration hardware, \$0.09M; systems

Table 4-1. Early Comm/Nav Research Laboratory In-Bay Configuration

ESTIMATED COST SUMMARY
($000)

WBS Cost Element		Non-Recurring (DDT&E)	Recurring (Production)	Total
Project Management		$ 4,000.0	$ 800.0	$ 4,800.0
System Engineering		2,400.0	1,000.0	3,400.0
Laboratory Equipment				
Experiment Unique				
Experiment Class	1 — RFI Noise	20.0	2.8	22.8
	3 — RF Propagation	179.1	240.1	419.2
	7 — Communication Relay	3,845.9	1,136.0	4,981.9
	9 — Laser Communication	13,932.6	2,396.2	16,328.8
	11 — Multibeam Antenna	1,196.6	149.9	1,346.5
	15 — Interfer. Nav.	308.7	114.9	423.6
	16 — Landmark Tracking	1,462.7	452.6	1,915.3
	Total	$20,945.6	$ 4,492.5	$25,438.1
Common Core		2,582.5	1,405.3	3,987.8
Control and Display		9,928.0	4,018.8	13,946.8
Integration Hardware		50.0	40.0	90.0
Ground Support Equipment				
Mechanical GSE		1,387.0	-0-	1,387.0
Electrical GSE		5,155.0	-0-	5,155.0
	Totals	$46,448.1	$11,756.6	$58,204.7

engineering, $3.40M and project management, $4.80M.

The total program cost for Early Comm/Nav Research Laboratory experiment equipment is shown, Table 4-1, at $58.20M.

The Early Comm/Nav Research Lab out-of-bay (Shuttle Orbiter bay) configuration would fly the same 7 experiment classes as the in-bay configuration. However the government furnished pallet would be deleted and replaced with an experiment unique Sortie Lab end dome, end dome ring, and set of deployable antenna arms and drive mechanism. The costs for these items are estimated as:

	Non-Recurring DDT&E	Recurring (Production)	Total
Sortie Lab End Dome	$ 400,000	$200,000	$ 600,000
Sortie Lab End Dome Ring	600,000	300,000	900,000
Deployable Antenna Arm and Drive	850,000	375,000	1,225,000
Total	$1,850,000	$875,000	$2,725,000

4.5 Supporting Cost Data

At level 5 the Experiment Unique equipment costs were broken out and presented on Table 4-2 by experiment class. DDT&E costs and production or Flight Equipment Costs are given on each of the 7 experiment classes. First flight only unit costs are shown and do not include costs of spares, backup, or equipment maintenance. Major refurbishment cost are likewise not included. Some minor refurbishment of the laboratory is suggested after each flight with major refurbishment accomplished at the beginning of the fifth year of operation.

In like manner, Tables 4-3 and 4-4 provide level 5 supporting cost estimate data for the Common Core and Control/Display equipment.

4.6 Cost Comparisons and Time Phasing

A comparison was made of the Early Comm/Nav Research Lab experiment costs (DDT&E plus Flight Unit) utilizing centralized common core equipment Figure 4-2, versus no common core equipment Figure 4-3 (each experiment providing all its equipment resulting in some equipment duplication). The controls/displays and ground support equipment remain

the same in either case, so the comparison is in the experiment equipment costs.

	Common Core Equipment Provided	No Common Core Equipment
Experiment Class 1	$ 22,800	$ 1,688,900
Experiment Class 3	419,200	2,081,000
Experiment Class 7	4,981,900	5,749,000
Experiment Class 9	16,328,800	18,415,000
Experiment Class 11	1,346,500	1,771,600
Experiment Class 15	423,600	879,000
Experiment Class 16	1,915,300	3,902,000
Common Core Equipment	3,987,800	none
Total	$29,425,900	$34,486,500

The difference is a savings of $5,060,600 by the utilization of common core equipment. This is another key point in emphasizing the value of the laboratory concept over flights of individual experiments. As the laboratory grows, and more experiment classes are added, the common core equipment employed will constitute a higher percentage of the total equipment, thus further improving the cost savings.

Much of the common core and display/control equipment and instrumentation can be traced to commercial sources. In this study commercial equipment sources were contacted for price information on their units as now used in ground laboratories or in aircraft flights. This price was then increased by appropriate factors to account for modification of the equipment to adaptation to a manned space laboratory flying short duration missions. The factors varied among equipment items as the need was assessed to upgrade the equipment to meet Sortie Lab postulated safety and utility standards by equipment redesign, component changes or material changes.

By far the most expensive Experiment Class is Laser Comm (Experiment Class Number 9). At $16.33M for its unique DDTE and production equipment costs, it represents well over half the cost of unique equipment for all seven experiment classes ($25.44M). If advantage could be taken of related laser communication hardware development being done by other U.S. Government agencies, the cost of the laser communication experiments on the Early Comm/Nav Research Lab might be significantly reduced.

Table 4-2. Communications/Navigation Research Laboratory

EXPERIMENT UNIQUE

EQUIPMENT LIST DOLLARIZED
($000)

	DDT&E Costs	Unit Qty Production Per Flight	Flight Equipment Costs
Experiment Class #1 - Terrestrial Sources of RF Noise and Interference			
Noise Figure Test Set	$ 20.0	1	$ 2.8
Total Cost	$ 20.0		$ 2.8
Experiment Class #3 - RF Propagation Experiment			
Polarization Resolver	$ 171.0	6	$ 240.0
Directional Coupler	8.1	1	.1
Total Cost	$ 179.1		$ 240.1
Experiment Class #7 - Communication Relay Experiment			
Antenna, VHF Crossed Slot	$ -0-	2-GFE	$ -0-
Parabolic Antenna (8')	1,590.0	1	190.0
Transmitter/Receiver VHF 1	85.5	5	160.9
Receiver, Ku-Band	450.0	1	130.0
Receiver, S-Band	4.0	1	40.0
Transmitter, Ku-Band	716.5	1	62.5
Switching, Diplexing & Preamp Un.	22.4	1	7.2
Modem	86.7	1	71.5
Demodulator	77.5	3	171.6
Modem, Wideband	317.0	2	210.0
D/A and A/D Converter	130.0	1	30.0
Antenna Scan Control Unit	32.0	1	6.0
Data Bit Stream Generator	32.3	1	6.3
Drive Servo Electronic	302.0	1	50.0
Total Cost	$ 3,845.9		$ 1,136.0

Reference: Vol. III, Table 2.1-9, pages 2-10/11

Table 4-2. Communications/Navigation Research Laboratory (Continued)

EQUIPMENT LIST DOLLARIZED
($000)

	DDT&E Costs	Unit Qty Production Per Flight	Flight Equipment Costs
Experiment Class #9 - Laser Communications			
Receiver Electronics, Laser	$ 700.0	1	$ 200.0
Laser Assembly, CO_2	6,550.0	1	550.0
Laser Assembly, Nd:YAG	2,450.0	1	450.0
Laser Link, doubled Nd:YAG	2,450.0	1	450.0
Laser Beacon, doubled Nd:YAG	230.0	1	30.0
Course Tracker	300.0	1	100.0
Transmitter Electronics, Laser	700.0	1	200.0
Optical Collimator	19.5	2	6.0
Laser Power Supply	92.1	2	57.2
Beam Expander Optics	250.0	2	100.0
Beam Deflector	171.5	4	250.0
Laser Power Meter	19.5	1	3.0
Total Cost	$13,932.6		$ 2,396.2
Experiment Class #11 - Multibeam Antenna Experiment			
Antenna, Multibeam	$ 775.0	1	$ 75.0
Antenna, Polarization Ref. Horn	7.9	1	.3
Crystal Detector	9.3	4	1.7
Ref. Signal Source (Transmitter)	19.5	1	3.0
Log Amplifier	14.2	8	17.1
Preamplifier	18.7	1	2.8
Antenna Servo Electronics	352.0	1	50.0
Total Cost	$ 1,196.6		$ 149.9

Reference: Vol. III, Table 2.1-9, pages 2-10/11

Table 4-2. Communications/Navigation Research Laboratory (Continued)

EQUIPMENT LIST DOLLARIZED
($000)

	DDT&E Costs	Unit Qty Production Per Flight	Flight Equipment Costs
Experiment Class #15 - Interferometric Navigation & Surveillance Techniques			
Antenna, Dual Dipole (L-Band)	$ 29.0	2	$ 8.0
Interferometric Boom Drive Elec.	40.0	1	8.0
Receiver, L-Band	74.0	2	66.0
Frequency Synthesizer & Driver	134.7	1 ea.	27.3
Calibration Signal Generator	31.0	1	5.6
Total Cost	$ 308.7		$ 114.9
Experiment Class #16 - Landmark Tracking			
Landmark Tracker	$ 390.0	1	$ 140.0
Servo Electronics (Landmark Tracker)	750.0	1	250.0
Correlation Electronics	150.0	1	50.0
Optical Collimator	12.7	2	2.6
Kalman Filter	160.0	1	10.0
Total Cost	$ 1,462.7		$ 452.6

Reference: Vol. III, Table 2.1-9, pages 2-10/11

Table 4-3. Communications/Navigation Research Laboratory

COMMON CORE

EQUIPMENT LIST DOLLARIZED
($000)

Equipment Description	DDT&E Costs	Unit Qty Production Per Flight	Flight Equipment Costs
Frequency Counter	$ 62.1	1	$ 11.3
RF Power Meter	24.5	2	8.6
AC/DC Voltmeter	42.7	2	14.3
Bit Error Counter	27.1	1	3.0
A/D Converter	32.3	2	8.6
Camera 16 mm	53.6	2	107.3
Camera Scope	10.4	2	2.2
Laser Telescope	460.0	1	187.5
RCVR Swept VHF	78.7	4	111.6
Attenuator Calibration	61.0	4	8.0
Scan Program Generator	43.1	3	34.8
Signal Formatter Unit	102.0	2	40.0
Power Calibration Unit	212.0	2	200.0
Fine Tracking Electronics	390.0	2	280.0
RF Variable Power Supply	150.0	2	150.0
Antenna LPDA VHF/UHF*	310.0	1	50.0
Wideband Power Divider	8.5	4	.6
Optical Antenna 18"	514.5	1	187.5
Total Cost	$ 2,582.5		$ 1,405.3

*Includes the antenna directivity switching assembly.

Reference: Vol. III, Table 2.1-8, page 2-9

Table 4-4. Communications/Navigation Research Laboratory

CONTROL AND DISPLAY

EQUIPMENT LIST DOLLARIZED
($000)

Equipment Description	DDT&E Costs	Unit Qty Production Per Flight	Flight Equipment Costs
Power Distribution	$ 1,500.0	3	$ 375.0
ECLS Display	100.0	2	50.0
X-Y Plotter	50.0	1	8.0
Caution/Warning Display	100.0	2	40.0
RF Sensor Control Panel	150.0	1	50.0
RF CRT Displays/Controls	800.0	2	325.0
Signal Patching Panel	25.0	1	5.0
RF Console Main Frame	3,370.0	1	1,500.0
Laser Console Main Frame	1,100.0	1	530.0
Telescope Gimbal Control	50.0	1	10.0
Visual Optics Controls	150.0	1	50.0
Tracking Display X-Y	80.0	1	20.0
Boresight Alignment Control	100.0	1	25.0
GNC Reference Display	50.0	1	10.0
Horizontal Sensor Monitor	150.0	1	50.0
TV Video Camera	50.0	4	40.0
Timer, Precision Clock	77.3	1	15.0
Computer, General Purpose	850.0	1	410.0
•Input/Output Keyboard		3	
Teleprinter	150.0	1	50.0
Tape Recorder, Digital	150.0	2	300.0
Tape Recorder, Video	96.4	1	21.5
Intercom	60.0	3	15.0
Phase Meter, Digital	500.0	1	50.0
Spectrum Analyzer/Oscilloscope	125.0	2	50.0
Oscillograph	94.3	1	19.3
Total Cost	$ 9,928.0		$ 4,018.8

Reference: Vol. III, Table 2.1-10, page 2-12

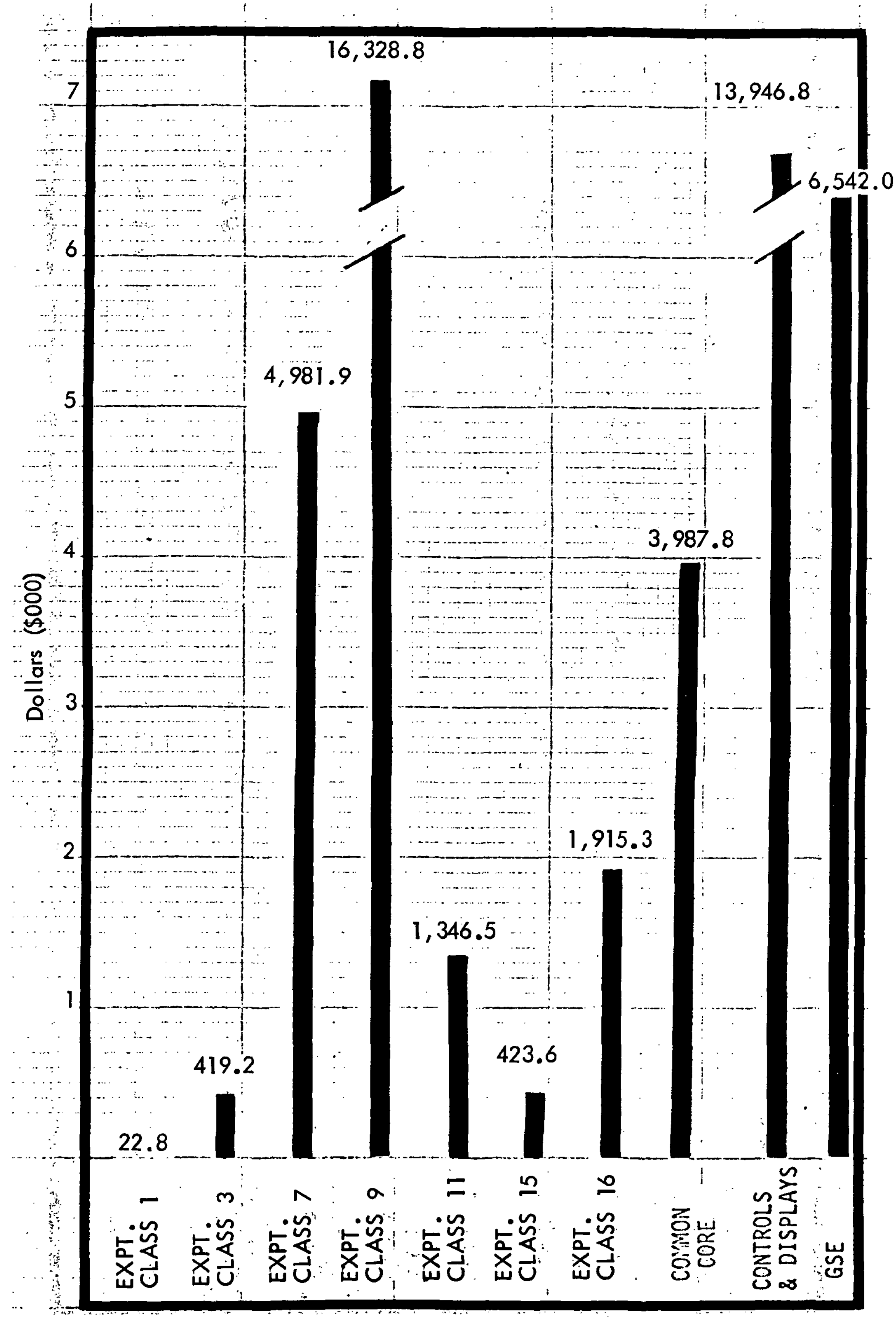


Figure 4-2. Communication Navigation Research Laboratory Experiment Costs (DDT&E & Flight) Utilizing Individual Experimentor Provided Common Core Equipment

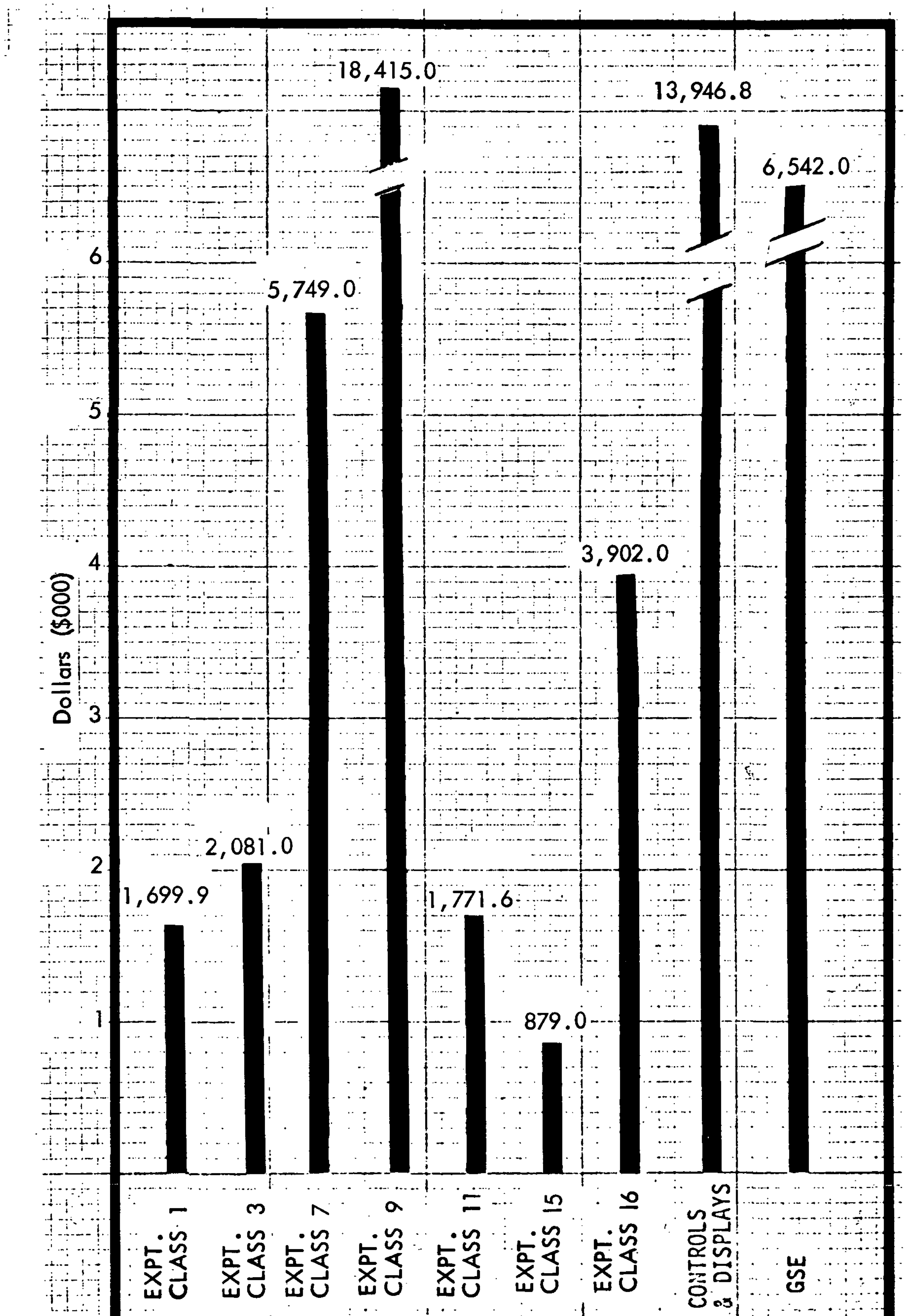


Figure 4-3. Communication Navigation Research Laboratory Experiment Costs (DDT&E & Flight) Utilizing Individual Experimentor Provided Common Core Equipment

The time to design, develop, test and evaluate (DDT&E) the Early Lab equipment/instrumentation plus the time needed for production of first flight hardware is estimated to require 4 years. However this 4 year time period includes 1 year of integration of the payload experiment equipment/ instrumentation into the Sortie Lab. Figures 4-3 and 4-4 reflect the time relationship. The actual breakdown would be 3 years of DDT&E and production activity and the fourth year given to experiment integration into the Sortie Lab. During the fourth year some equipment production would be carried out while the integration of all ready produced equipment would be taking place. Thus some time overlap of production-integration would occur.

Table 4-5 shows the suggested fund phasing for DDT&E and production costs for the Early Comm/Nav Research Laboratory experiment equipment for the 4 year period prior to Early Lab launch.

Table 4-5. Early Lab Equipment Funding Schedule

Cost Element	CY Before Launch				Launch
	L-4	L-3	L-2	L-1	Total $M
Experiment Unique Equipment	$ 3.00	$ 6.00	$10.00	$ 6.44	$25.44
Common Core Equipment	.50	1.00	2.48	-	3.98
Controls/Displays	2.00	3.00	4.95	4.00	13.95
Ground Support Equipment	2.00	2.00	2.54	-	6.54
Experiment Integration Hardware	-	-	0.04	0.05	0.09
Systems Engineering	1.50	1.90	-	-	3.40
Project Management	1.00	1.04	1.72	1.04	4.80
CY Total $M	$10.00M	$14.94	$21.73	$11.53	$58.20M
Cumm. $M	$10.00M	$24.94	$46.67	$58.20	-

4.7 Individual Experiment Class Equipment Lists-Early Laboratory Experiments

Equipment lists for each of seven Comm/Nav experiment classes recommended for an Early Laboratory Sortie Lab mission as given on pages 4-29 through 4-35. The individual lists were derived from an experiment class equipment compilation summary used in preparing the laboratory layouts given in Volume III. Each list identifies all units required to support a given experiment class exclusive of any commonality which may be realized if two or more experiments are combined.

Caution should be exercised in interpreting and using these lists as guides to implementation of individual class experiments. For example, while a general purpose computer may be advantageous in controlling and processing the simultaneous multi-requirements of the seven experiment classes, it probably is not justified, or desirable, on an individual experiment class basis. The computer has been included, however, to be consistent with the consolidated Early Laboratory equipment list. Similarly, the performance requirements for a given component used in a single experiment may be relaxed from those imposed on it when dedicated to multiple experiments. The reduced secondary power handling requirement to support one experiment illustrates this point.

In summary, the attached equipment lists offer a convenient means to make a preliminary assessment of the relative complexity and equipment complement of the selected experiment classes for flight on Shuttle Orbiter development missions in 1978 and 1979 or on other possible manned flight opportunities that might occur in the mid- to late-1970s. However, it should not be concluded that these lists constitute an optimum approach for applications which depart from the original guidelines; namely, a 7-day, low-altitude, manned-laboratory mission incorporating the seven experiment classes as an integrated Comm/Nav research payload.

EQUIPMENT LIST

TERRESTRIAL SOURCES OF RF NOISE AND INTERFERENCE

	Quantity
Experiment-Unique	
1. Noise Figure Test Set	1
Common-Core	
1. Camera, Scope	1
2. Antenna Directivity Switch Assembly	3
3. Frequency Counter	1
4. AC/DC Voltmeter	1
5. A/D Converter	1
6. Antenna, LPDA	1
7. Receiver, Swept Band, VHF/UHF	4
8. Attenuator Calibration Unit	3
9. Scan Program Generator	3
10. Signal Formating Unit	2
11. Wideband Power Divider	4
12. RF Variable Power Supply	1
13. Power Calibration Unit	2
Control and Display	
1. Power Distribution	1
2. Caution/Warning Display	1
3. RF CRT Displays/Controls	1
4. Signal Patching Panel	1
5. RF Console Main Frame	1
6. Timer, Precision Clock	1
7. Computer, General Purpose	1
8. Tape Recorder, Digital	1
9. Intercom	1
10. Spectrum Analyzer/Oscilloscope	1

EQUIPMENT LIST

RF PROPAGATION EXPERIMENT

	Quantity
Experiment-Unique	
1. Polarization Resolver	6
2. Directional Coupler	1
Common-Core	
1. Camera, Scope	1
2. Frequency Counter	1
3. RF Power Meter	1
4. AC/DC Voltmeter	1
5. A/D Converter	1
6. Antenna, LPDA	1
7. Antenna Directivity Switch Assembly	3
8. Receiver, Swept Band, VHF/UHF	3
9. Attenuator Calibration Unit	4
10. Scan Program Generator	3
11. Signal Formating Unit	2
12. Wideband Power Divider	4
13. RF Variable Power Supply	1
14. Power Calibration Unit	2
Controls and Display	
1. Power Distribution	1
2. Caution/Warning Display	1
3. RF CRT Displays/Controls	1
4. Signal Patching Panel	1
5. RF Console Main Frame	1
6. Timer, Precision Clock	1
7. Computer, General Purpose	1
8. Tape Recorder, Digital	1
9. Intercom	1
10. Spectrum Analyzer/Oscilloscope	1

EQUIPMENT LIST

COMMUNICATION RELAY EXPERIMENT

		Quantity
Experiment-Unique		
1.	Antenna, VHF Crossed Slot	2
2.	Parabolic Antenna (8 ft.)	1
3.	Receiver, VHF	5
4.	Receiver, Ku-Band	1
5.	Receiver, S-Band	1
6.	Transmitter, VHF	1
7.	Transmitter, Ku-Band	1
8.	Switching, Diplexing and Preamplification Unit	1
9.	Modem	1
10.	Demodulator	3
11.	Modem, Wideband	2
12.	D/A and A/D Converter	1
13.	Antenna Scan Control Unit	1
14.	Data Bit Stream Generator	1
Common-Core		
1.	Frequency Counter	1
2.	RF Power Meter	1
3.	AC/DC Voltmeter	1
4.	Bit Error Counter	1
5.	Antenna, LPDA	1
6.	Antenna Directivity Switch Assembly	1
7.	RF Variable Power Supply	1
Controls and Displays		
1.	Power Distribution	1
2.	Caution/Warning Display	1
3.	RF Sensor Control Panel	1
4.	RF CRT Displays/Controls	1
5.	Signal Patching Panel	1
6.	RF Console Main Frame	1
7.	Timer, Precision Clock	1
8.	Computer, General Purpose	1
9.	Tape Recorder, Digital and Intercom System	1
10.	Spectrum Analyzer/Oscilloscope	1

EQUIPMENT LIST

LASER COMMUNICATIONS

		Quantity
Experiment-Unique		
1.	Receiver Electronics, Laser	1
2.	Laser Assembly, CO_2	1
3.	Laser Assembly, Nd:YAG	1
4.	Laser Link, doubled Nd:YAG	1
5.	Laser Beacon, doubled Nd:YAG	1
6.	Coarse Tracker	1
7.	Transmitter Electronics, Laser	1
8.	Optical Collimator	2
9.	Laser Power Supply	2
10.	Beam Expander Optics	2
11.	Beam Deflector	4
12.	Laser Power Meter	1
Common-Core		
1.	Bit Error Counter	1
2.	A/D Converter	1
3.	Optical Antenna - 18 in.	1
4.	Servo Electronics (Optical Antenna - 18 in.)	1
5.	Fine Tracker Electronics	2
Controls and Displays		
1.	Power Distribution	1
2.	Caution/Warning Display	1
3.	Laser Console Main Frame	1
4.	Telescope Gimbal Controls	1
5.	Visual Optics Controls	1
6.	Tracking Display, X-Y	1
7.	Boresight Alignment Controls	1
8.	GNC Reference Display	1
9.	TV Video Camera	1
10.	Timer, Precision Clock	1
11.	Computer, General Purpose	1
12.	Tape Recorder, Digital	1
13.	Intercom	1
14.	Spectrum/Analyzer/Oscilloscope	1

EQUIPMENT LIST

MULTIBEAM ANTENNA EXPERIMENT

		Quantity
Experiment-Unique		
1.	Antenna, Multibeam	1
2.	Antenna, Polarization Ref. Horn	1
3.	Crystal Detector	4
4.	Reference Signal Source (Transmitter)	1
5.	Log Amplifier	8
6.	Preamplifier	1
Common-Core		
1.	Camera, Scope	1
2.	Frequency Counter	1
3.	RF Power Meter	1
4.	AC/DC Voltmeter	1
5.	A/D Converter	1
6.	RF Variable Power Supply	1
Controls and Displays		
1.	Power Distribution	1
2.	Caution/Warning Display	1
3.	RF Sensor Control Panel	1
4.	RF CRT Displays/Controls	1
5.	Signal Patching Panel	1
6.	RF Console Mainframe	1
7.	TV Video Camera	1
8.	Timer, Precision Clock	1
9.	Computer, General Purpose	1
10.	Oscillograph	1
11.	Tape Recorder, Digital	1
12.	Intercom	1
13.	Spectrum Analyzer/Oscilloscope	1

EQUIPMENT LIST

INTERFEROMETRIC NAVIGATION AND SURVEILLANCE TECHNIQUES

	Quantity
Experiment-Unique	
1. Antenna, Dual Dipole (L-Band)	2
2. Boom Support	2
3. Interferometric Boom Drive Electronics	1
4. Receiver, L-Band	2
5. Frequency Synthesizer and Driver	1
6. Calibration Signal Generator	1
Common-Core	
1. Frequency Counter	1
2. AC/DC Voltmeter	1
3. Camera, 16 mm	1
4. RF Variable Power Supply	1
Controls and Displays	
1. Power Distribution	1
2. Caution/Warning Display	1
3. RF CRT Displays/Controls	1
4. Signal Patching Panel	1
5. RF Console Main Frame	1
6. TV Video Camera	1
7. Timer, Precision Clock	1
8. Computer, General Purpose	1
9. Tape Recorder, Digital	1
10. Intercom	1
11. Phase Meter, Digital	1
12. Spectrum Analyzer/Oscilloscope	1

EQUIPMENT LIST

LANDMARK TRACKING

	Quantity
Experiment-Unique	
1. Landmark Tracker	1
2. Servo Electronics (Landmark Tracker)	1
3. Correlation Electronics	1
4. Optical Collimator	2
5. Kalman Filter	1
Common-Core	
1. Camera, 16 mm	1
2. Optical Antenna - 18 in.	1
3. Servo Electronics (Optical Antenna - 18 in.)	1
4. Fine Tracker Electronics	1
Controls and Displays	
1. Power Distribution	1
2. Caution/Warning Display	1
3. Laser Console Mainframe	1
4. Telescope Gimbal Controls	1
5. Visual Optics Controls	1
6. Tracking Display, X-Y	1
7. Boresight Alignment Controls	1
8. GNC Reference Display	1
9. Horizon Sensor Monitor	1
10. TV Video Camera	1
11. Timer, Precision Clock	1
12. Computer, General Purpose	1
13. Tape Recorder, Digital	1
14. Tape Recorder, Video	1
15. Intercom	1
16. Spectrum Analyzer/Oscilloscope	1

4.8 Cost Comparison

In the course of specifying equipment for conduct of the Comm/Nav Research Lab experiments, a selection was made of commercial type equipment that could be adapted for use on manned orbital missions. This examination of commercial equipment led to the thinking that an interesting cost comparison could be made on the idea that a Comm/Nav orbital research lab might evolve from equipment that could be specified for research in ground-based facilities.

Accordingly, a cost analysis was made to show how equipment/instrumentation costs for Comm/Nav experiments would increase in price from use in a ground-based lab to a Shuttle supported lab to an automated spacecraft lab. Figure 4-4 shows in pictorial concept form the utilization of the above three types of labs.

A ground based laboratory would feature:

- Extensive use of research, engineering, and technician personnel.
- Capital investment of laboratory equipment for the long term use.
- Extensive use of commercial/equipment instrumentation.
- Equipment changes on a routine and sometimes frequent basis.
- Scheduled maintenance.
- Complete control of experiments within the lab.

Such a ground-based laboratory would be housed in a research building at some government, industry or university institution. Such labs are, of course, common and are in every day use.

The experiments designated for the Early Comm/Nav Lab are depicted in Figure 4-4 in a ground-based facility. The equipment/instrumentation costs are designated as unity for the ground-based laboratory.

It is recognized that the ground-based lab would not be capable, of course, of functionally duplicating the environmental or mission dependent characteristics of an orbiting vehicle, and therefore it is incorrect to assume

that the research measurements needed on the seven experiment classes for the Early Comm/Nav Lab could be made on the ground. However, for purposes of cost comparison on an equipment basis only, the reader is asked to envision such a ground facility.

Figure 4-4 next shows the Space Shuttle supported manned laboratory. Here the ground-based laboratory equipment for the seven Early Comm/Nav experiment classes is modified and/or qualified to allow it to be flown in space. This modification/qualification process could increase the space lab equipment costs by a factor of three or four over the ground-based laboratory equipment.

A Sortie Lab would feature:

- On-board experimenter personnel
- Shuttle Sortie missions
- Some commercial equipment/instruments modified for manned, short duration missions
- Some experiment changes during mission
- Experiment control within lab, but support from ground mission operations, minimum automation
- No planned maintenance

Finally, Figure 4-4 depicts an automated spacecraft laboratory to conduct Comm/Nav experiments.

This laboratory would feature:

- Long flight duration missions
- High reliability equipment/instruments (space qualified)
- Equipment changes only during Shuttle revisits
- Automated programmed experiment sequence or ground control
- Maintenance on Shuttle revisits

Preliminary analysis indicates that the equipment for the Early Comm/Nav seven experiments would increase in costs by a factor of approximately eight to 10 over the same equipment used in the ground-based laboratory. The reason for the increased cost is predicated on the need for the equipment to be qualified to high reliability specifications for operation over long duration missions and also the need for adding equipment for the purpose of full automation of the experiment program.

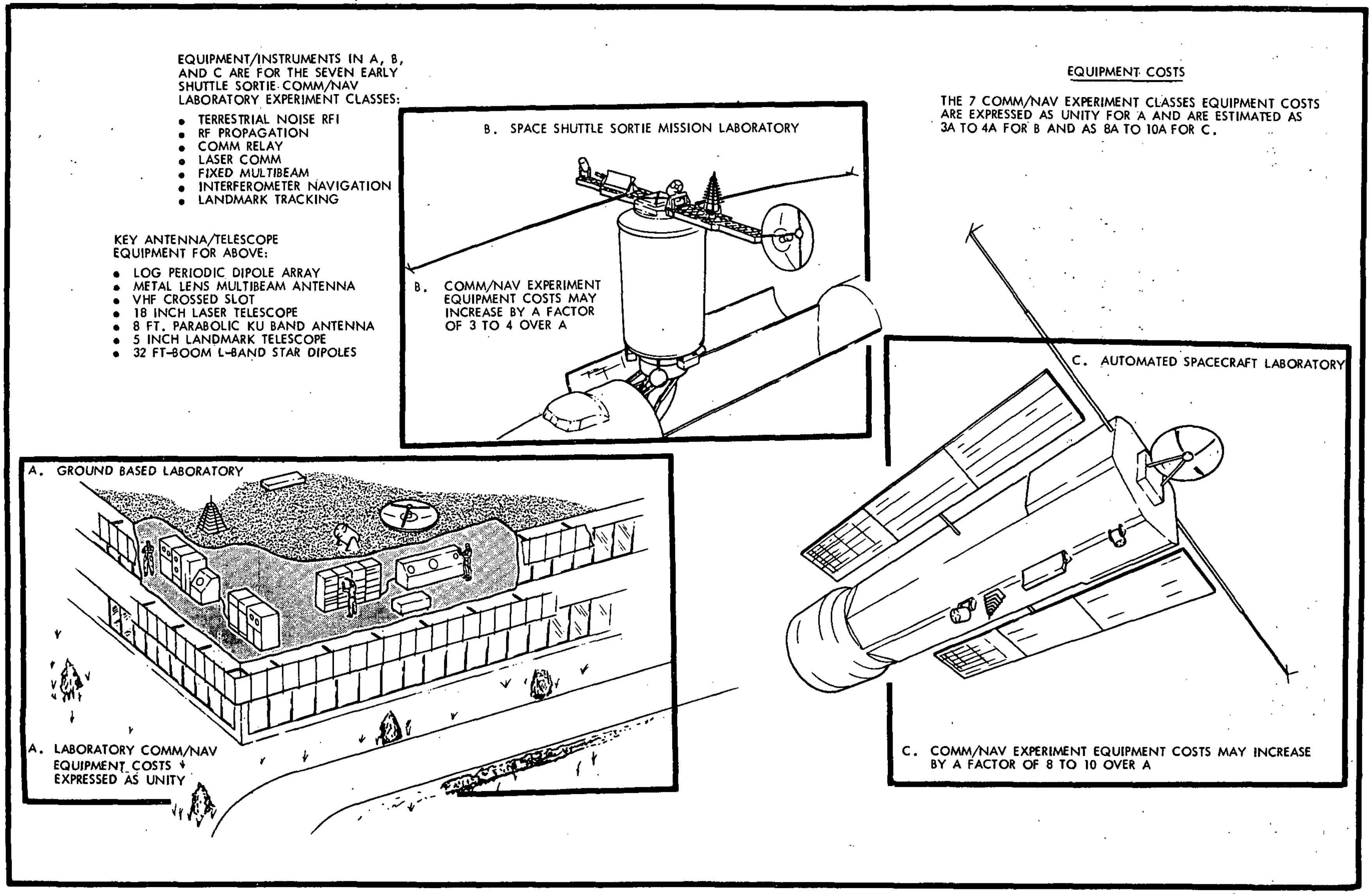


Figure 4-4. Comm/Nav Research Results in Changing Requirements for Equipment Utilization as the Laboratory Experiments Move from Ground Facilities to Shuttle Sortie Space Missions to Fully Automated Spacecraft Flights. Equipment Costs Reflect These Changes.

SECTION 5

SUPPORTING RESEARCH AND TECHNOLOGY (SRT)

The SRT requirements defined in this Section suggest work that should be accomplished in order to lower the mission performance risks at the start of Phase D of the Comm/Nav Shuttle supported research laboratory.

The seven experiment classes selected for research conduct in the initial flights of the Early Comm/Nav Laboratory and the equipment/ instrumentation associated with these seven, experiment classes are based, to the extent that it was practical and cost effective, on proven technology and current hardware adapted to Early laboratory mission and experiment measurement requirements.

Thus, there is virtually no concern regarding the feasibility of the proposed implementation of the Early Comm/Nav Laboratory. There are, however, particular hardware areas that offer the potential of cost reduction and increased mission data gathering results if SRT work is performed.

5.1 Identification of SRT Items

Twenty items of SRT hardware have been identified as pertinent to the 18 Comm/Nav experiment classes.

Table 5-1 lists these 20 SRT items and shows by the X mark where they are applicable to the 18 experiment classes. Note that many are associated with more than one class. Thus, an investment in an item of SRT could benefit more than one set of experiment measurements.

Each SRT item is aimed at specific objectives--shown also on Table 5-1. The implication is that solution to the objectives via the SRT item suggested will effectively increase the value of the experiment class data.

5.2 SRT Applicability, Necessity, and Confidence

Three helpful bases for ranking the importance of the 20 SRT items are:

Table 5-1. Summary Comm/Nav SR&T Item Applications

	ITEM NAME	EXPERIMENT APPLICATION OF ITEM: EARLY LAB							FIRST ALTERNATIVES					REMAINDER						OBJECTIVES OF PROPOSED ACTIVITY
		TERRESTRIAL SOURCES AND NOISE	R. F. PROPAGATION	INTERFEROMETER	COMMUNICATION RELAY	LASER-BEAM COMMUNICATION	MULTIBEAM ANTENNA	LANDMARK TRACKING	ON-BOARD SIGNAL PROCESSING	PLASMA PROPAGATION	SUSCEPTIBILITY OF TERRESTRIAL SERVICES	RANGE AND RANGE RATE NAVIGATION	HORIZON ALTITUDE AND RADIANCE PROFILE	OPTICAL PROPAGATION	DIRECT BROADCAST	ELF/VLF	LARGE REFLECTOR DEPLOYMENT	NARROW BEAM TRACKING	LASER RANGING	
1	ULTRAWIDEBAND DIRECTIONAL ANTENNA	X	X		X					X	X									• ESTABLISH AND ANALYZE CANDIDATE CONFIGURATIONS • SYNTHESIZE DESIGN WITH COMPUTER • FABRICATE BRASSBOARD AND TEST ON RANGE
2	WIDEBAND POLARIMETER		X																	• IDENTIFY KEY FREQUENCY SENSITIVE ELEMENTS • DETERMINE APPROACH FOR 10:1 FREQUENCY COVERAGE • DESIGN IMPROVED PROCESSING NETWORK
3	VHF DIGITAL PHASEMETER			X																• IDENTIFY APPROACH FOR RELIABLE HIGH RESOLUTION 60 MHZ RF PHASEMETER • BREADBOARD-DEMONSTRATE-OPTIMIZE
4	REMOTE CONTROL FILTER	X			X				X											• DETERMINE ELECTRICAL NOISE • ESTABLISH PREFERRED DESIGN • FABRICATE AND TEST
5	ADAPTIVE ERP CONTROL								X		X									• IDENTIFY METHODS OF POWER CONTROL FOR FDM AND TDM SYSTEMS • DEMONSTRATE PERFORMANCE
6	REFLECTOR DESIGN AND SIMULATION STUDIES						X								X		X			• INVESTIGATE CANDIDATE MATERIALS • RESEARCH LITERATURE ON DESIGN APPROACHES • SELECT PREFERRED CONCEPT • EVALUATE DEPLOYMENT METHODS
7	SILENT KEYBOARD	X	X	X	X	X	X		X		X				X					• INVESTIGATE ACOUSTIC AND ELECTRICAL NOISE GENERATION MECHANISMS • EVALUATE OPTICAL SWITCHING SCHEMES • SELECT DESIGN APPROACH AND BREADBOARD
8	SOLID-STATE DISPLAY	X	X	X	X				X	X	X	X			X					• EVALUATE STATE-OF-ART IN S. S. DISPLAYS • DETERMINE CANDIDATE • IDENTIFY AND SPONSOR DEVELOPMENT
9	ASTRONAUT LOCATION ROD	←							ALL										→	• SYNTHESIZE ASTRONAUT ACTIVITY IN LABS • DEFINE BASELINE ROD RESTRAINT • INTEGRATE PHYSIOLOGICAL, SAFETY AND WORK FACTORS
10	RFI-EMI PROTECTION (CAN)	X	X	X	X		X		X	X		X				X				• EVALUATE STATE OF ART IN SHIELDING AND FILTERING • REVIEW PRIOR SPACE VEHICLE SIGNATURES • SIMULATE EXPECTED SORTIE CAN EQUIPMENT CONFIGURATIONS TO OBTAIN RFI SIGNATURES • EVALUATE EFFECTS ON EXPERIMENTS AND DEFINE
11	COMMERCIAL EQUIPMENT TRANSLATION	←							ALL										→	• INSPECT REPRESENTATIVE COMMERCIAL CANDIDATES • RESEARCH MATERIALS AND METHODS • DETERMINE REQUIRED IMPROVEMENTS • RUN PILOT R&D - SPONSOR INDUSTRY FOLLOW-ON
12	IMPROVED LASER DETECTOR					X								X					X	• CONVERT RESEARCH DEMO IN BELL JAR TO SPACE-USE HARDWARE • EVALUATE COOLING • DEVELOP CROSS FIELD P. M. T. FOR 1.06 MICRON
13	TUNEABLE LASER					X								X						• DEVELOP LASER TUNEABLE OVER >±10 GHZ HAVING MINIMUM OUTPUT OF 50 MW AT 10.6 MICRONS • INVESTIGATE HEATPIPE AND THERMO-ELECTRIC COOLING
14	IMPROVED UNIVERSAL RACK-TRAY STRUCTURE	X	X	X	X				X	X	X	X			X	X		X		• ADAPT PROVEN, LIGHTWEIGHT, RUGGED, COMPACT "ATR" EQUIPMENT SCHEME TO MANNED C/N MODULE
15	SIGNAL SWITCHING MATRIX	←							ALL										→	• DEVELOP IMPROVED COMPLEX SIGNAL SWITCHING SUBSYSTEM ESSENTIAL FOR VERSATILE LABORATORY
16	IMPROVED DOPPLER ANALYSIS SOFTWARE	X		X					X											• EVALUATE VARIOUS ALGORITHMS FOR IMPROVED SPEED, ACCURACY AND LOW COST. • RE-EXAMINE F. F. T., F. H. T. AND ALLIED ALGORITHMS TRY TO APPLY.
17	EFFICIENT ANTENNA FOR VLF															X				• EVALUATE MATERIALS FOR VLF/ELF ANTENNAS • EXAMINE AND ANALYZE ALTERNATIVE CONCEPTS • DEFINE PREFERRED APPROACHES AND PERFORMANCE
18	ADAPTATION OF EVA MANIPULATORS FOR ANTENNA DEPLOYMENT	X	X	X	X	X	X			X	X	X		X	X		X	X		• DEFINE METHOD OF INTERFACING SHUTTLE MANIPULATORS WITH VARIOUS COMM/NAV ANTENNAS TO OBVIATE NEED FOR SEPARATE DEPLOYMENT/POINTING FACILITIES • INVESTIGATE HOW BEST TO STORE, RETAIN/RELEASE ANTENNA ASSEMBLIES, RESTRAIN CABLE, PROGRAM USE
19	IMPROVED KALMAN FILTER FOR POST-ACQUISITION DATA ACCURACY ENHANCEMENT	X	X	X				X						X				X	X	• EXAMINE EXISTING STATE-OF-ART IN COMPUTER STATISTICAL FILTERING TECHNIQUES – RELATE TO SPECIFIC COMM/NAV EXPERIMENTS • ATTEMPT TO DEFINE IMPROVED ALGORITHMS FOR COMM/NAV LAB USE
20	INTERCHANGEABLE MICROWAVE PACKAGES AND COMMON REFLECTOR	X	X	X	X					X	X	X			X		X			• DESIGN A PACKAGING SCHEME FOR PRECISION EVA SUBSTITUTION OF VARIOUS MICROWAVE HEADENDS ON A SINGLE (COMMON) DISH • EXTEND CONCEPT TO DEVELOP REMOTE HEADEND CHANGES USING SCHEME SIMILAR TO MOVIE CAMERA LENS TURRET

Applicability — Number of experiment classes to which the SRT item is applicable, Figure 5-1

Necessity — Each SRT item has been ascribed a necessity level on a scale of zero to unity, Figure 5-2

Confidence — Risk analysis; degree to which it is thought the SRT work will be totally successful, Figure 5-3.

Examination of the above Figures indicates:

1) Most of the SRT items will aid more than one experiment class, Figure 5-1, and three SRT items apply to all 20 classes.

2) Five SRT items, Figure 5-2, are considered essential to best conduct of their associated experiment class or classes.

3) Overall, if it thought that a high level of confidence could be assigned to successfully meeting goals/objectives of the proposed 20 SRT items, Figure 5-3.

5.3 SRT Descriptions

The 20 SRT items of Table 5-1 are summarized on the following pages. Implicit in the information on each item is data, where appropriate, on the objectives, background, problems, approach, and justification of the SRT item. Common to all descriptions is a standard format table. An X in the box below the SRT task means work should be performed on that task; no X, or a blank, means SRT work probably not needed.

The 20 SRT descriptions begin on page 5-7. In several instances it was thought important that the illustrative material pertaining to the SRT item be shown on the page facing the descriptive text/table. Where no illustrative material was needed the facing page is blank.

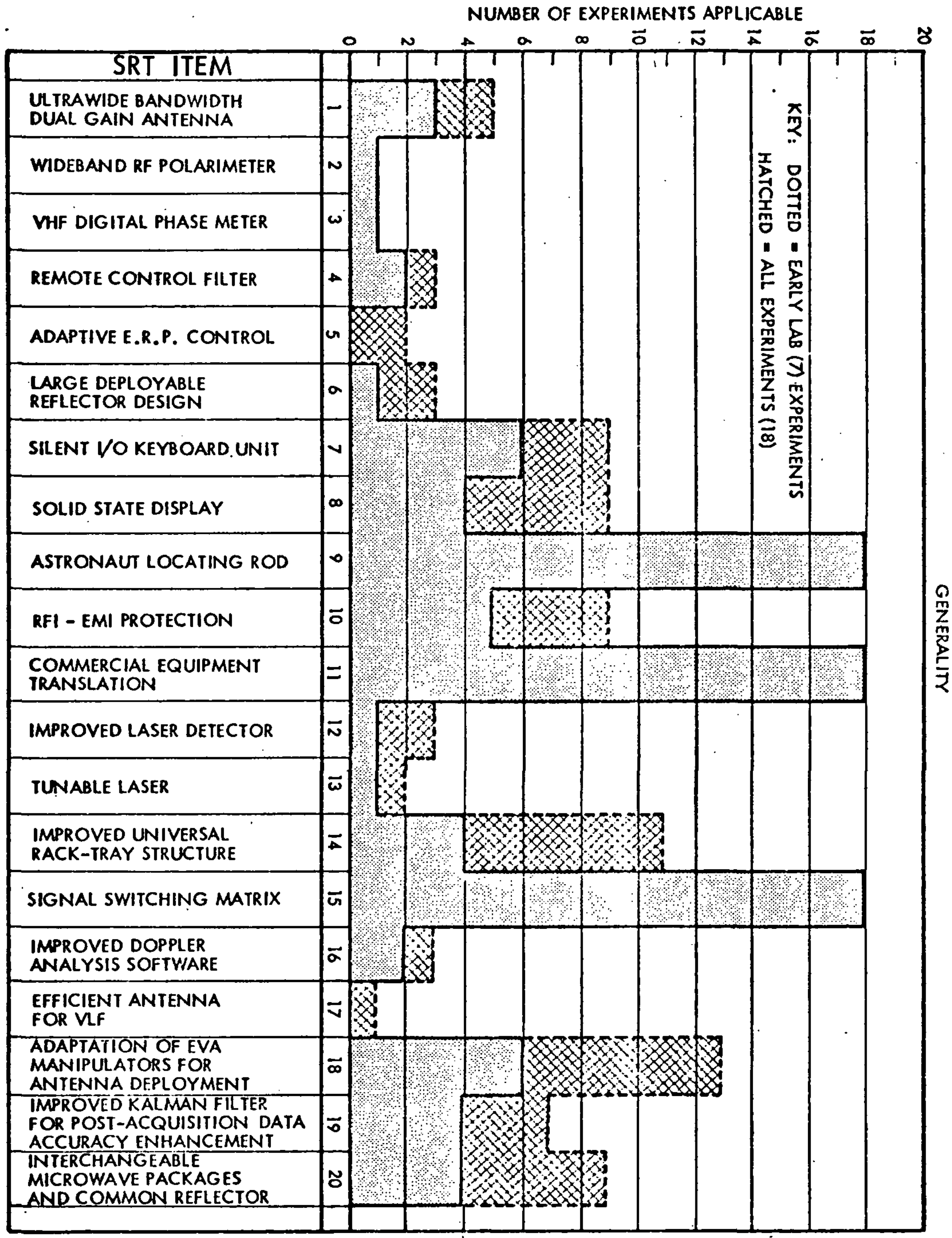


Figure 5-1. Applicability — Number of Experiment Classes to Which the SRT Item is Applicable.

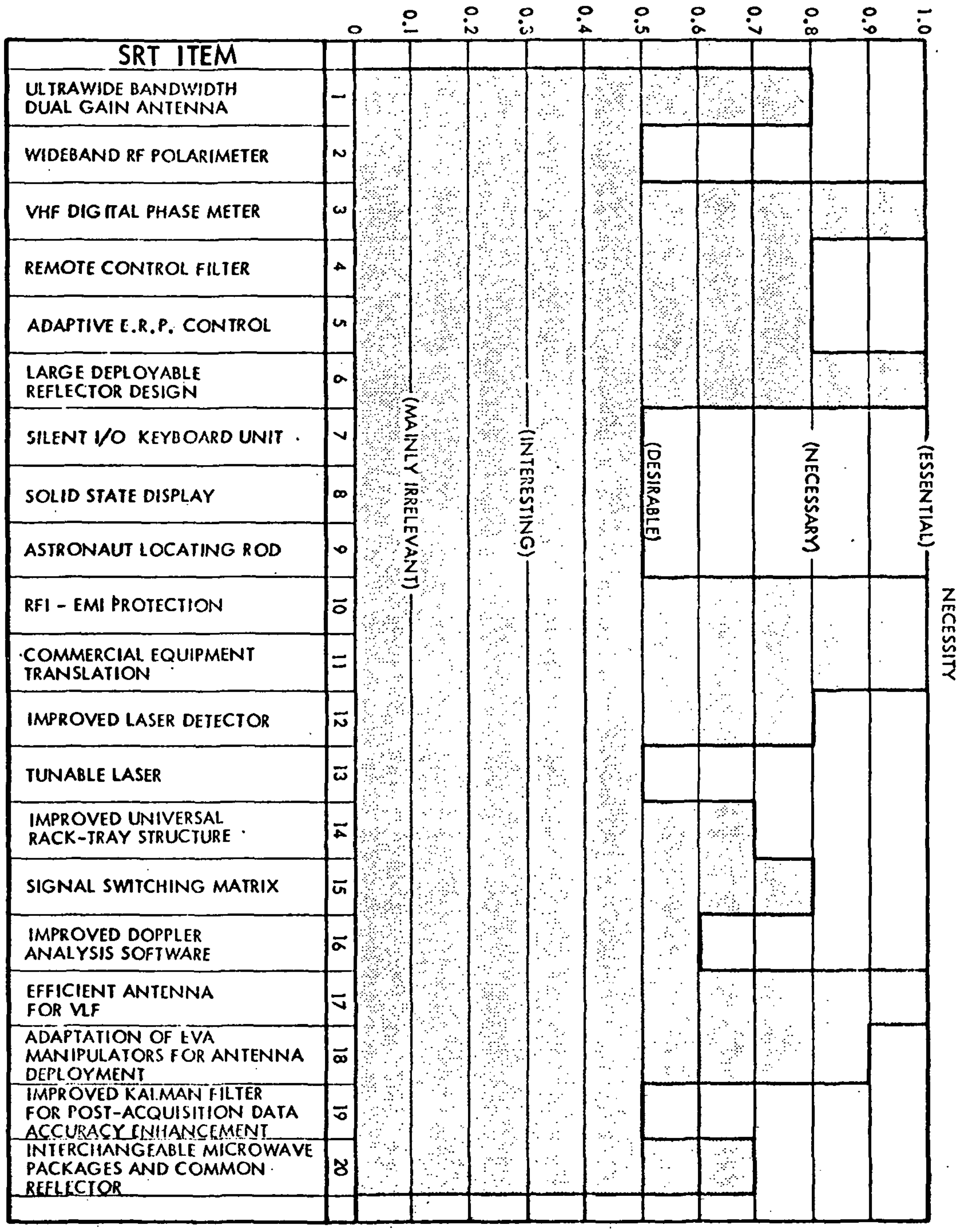


Figure 5-2. Necessity — Each SRT Item Has Been Ascribed a Necessity Level on a Scale of Zero to Unity.

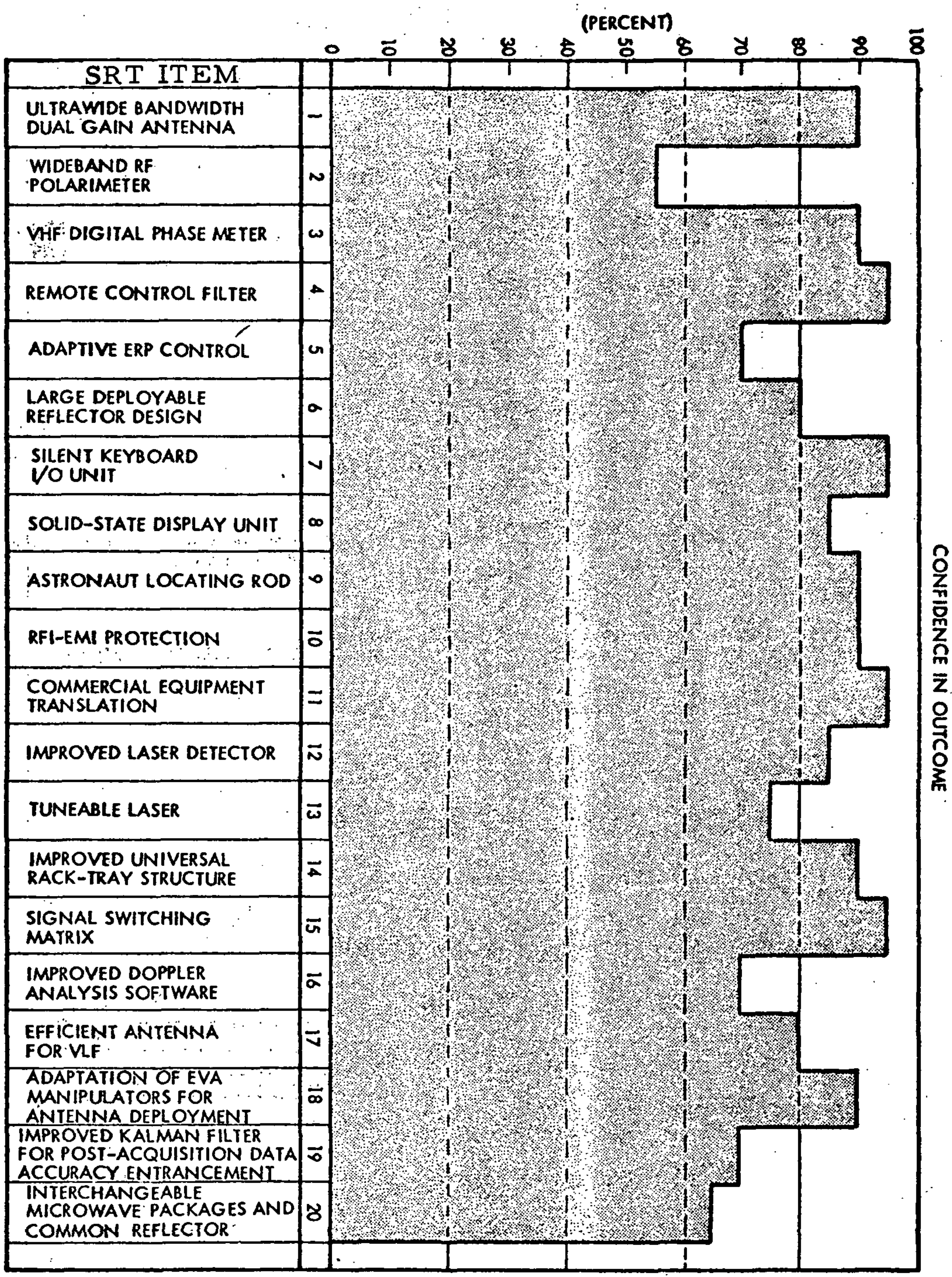
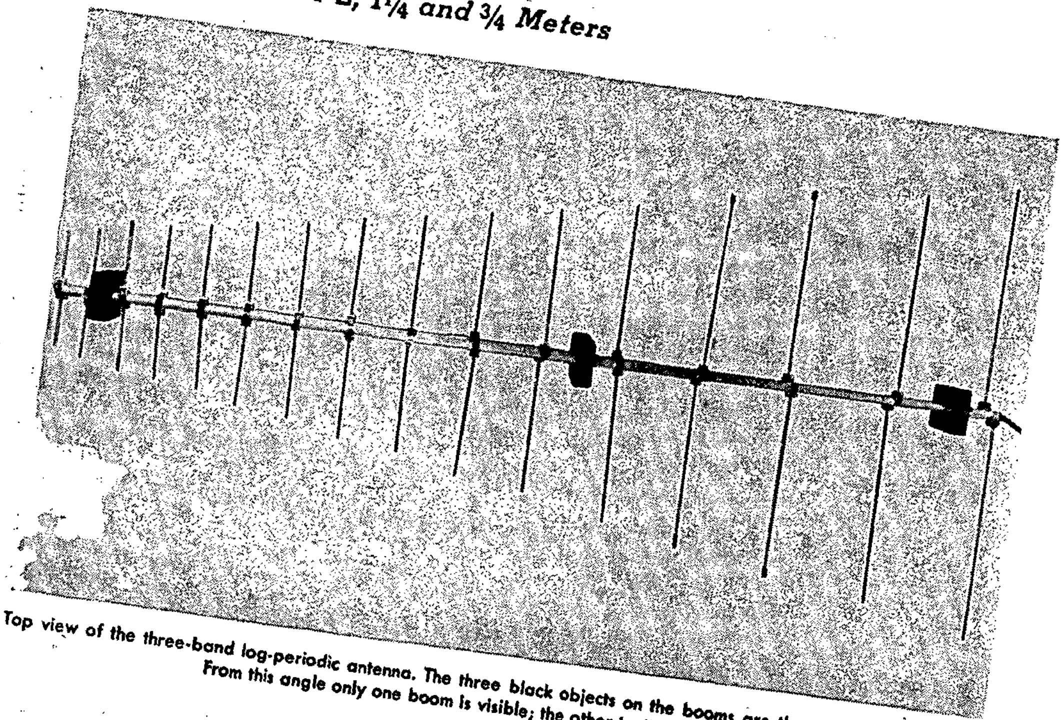


Figure 5-3. Confidence — Risk Analysis; Degree to Which It Is Thought the SRT Work Will Be Totally Successful.

One Antenna for 2, 1¼ and ¾ Meters



Top view of the three-band log-periodic antenna. The three black objects on the booms are the wood block spacers. From this angle only one boom is visible; the other is directly below it.

Figure 5-4. Typical Single Polarization LPDA

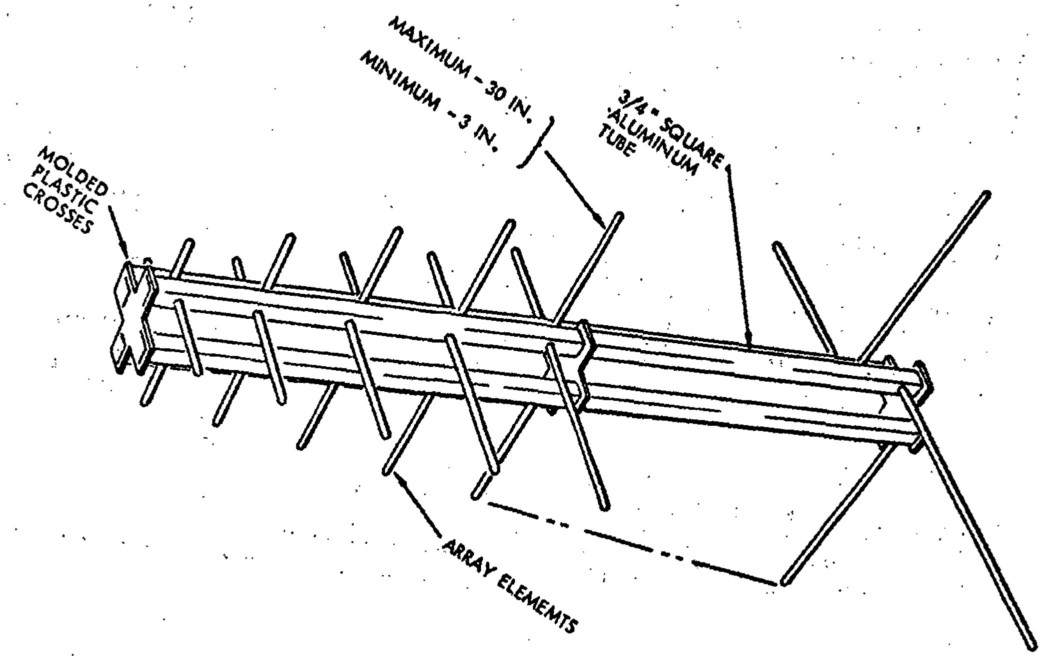


Figure 5-5. Suggested Dual Polarization Version

SR&T TASK DESCRIPTION

Item 1. Ultra Wideband Directional Antenna

Objective

To develop an antenna that exhibits the following properties

- Operates over the frequency range of 100 - 1000 MHz
- Provides a modest directional radiation pattern and gain
- Maintain an impedance match over the frequency range (VSWR ≤ 1.5)
- Minimum size and weight
- Construction compatible with space deployment and use
- Provide dual simultaneous and independent linear E and H polarization outputs

Technical Problems

- 10:1 frequency range can be accommodated by log periodic dipole structure, but this is linear - two units are needed for E and H service

- Size and weight considerations suggest physically integrating two LPDA units but this may modify the desirable characteristics of both

- Minimizing overall length, and maximizing minimum element spacing are mutually conflicting objectives

Approach

- One potential candidate is a dual version of the LPDA as illustrated in Figure 5-4, which is derived from the regular log periodic antenna shown in Figure 5-5.

SRT TASK →	Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
		X	X	X	X		X	X	X	X	X	X	X

SR&T TASK DESCRIPTION

Item 2. Wideband Polarimeter

Background

- Simplest polarimeter technique involves astronaut physically rotating a dipole and locating null
- Mechanical schemes involve bearing less reliable
- Phasing of fixed orthogonals allows simultaneous use for other experiments
- Proposed polarimeter is an RF assembly of transmission line phase shifters, attenuators and hybrid junctions
- Its purpose is to combine the outputs from the two fixed, orthogonal, linear antennas and in conjunction with a servo subsystem determine the polarization of any incident signal
- Conventional methods use hardware configuration that make the performance frequency dependent
- Calibration can correct errors over only a narrow frequency range
- If multiple polarimeters are used, each dedicated to a small portion of the band, complex switching is needed and severe size and weight penalties accrue

Objective

- Review literature and evaluate alternative methods of measuring polarization arrival angle
- Identify fundamental component and material problems limiting bandwidth extension
- Develop, fabricate and test improved hardware

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X		X	X	X	X	X	X	X	X		

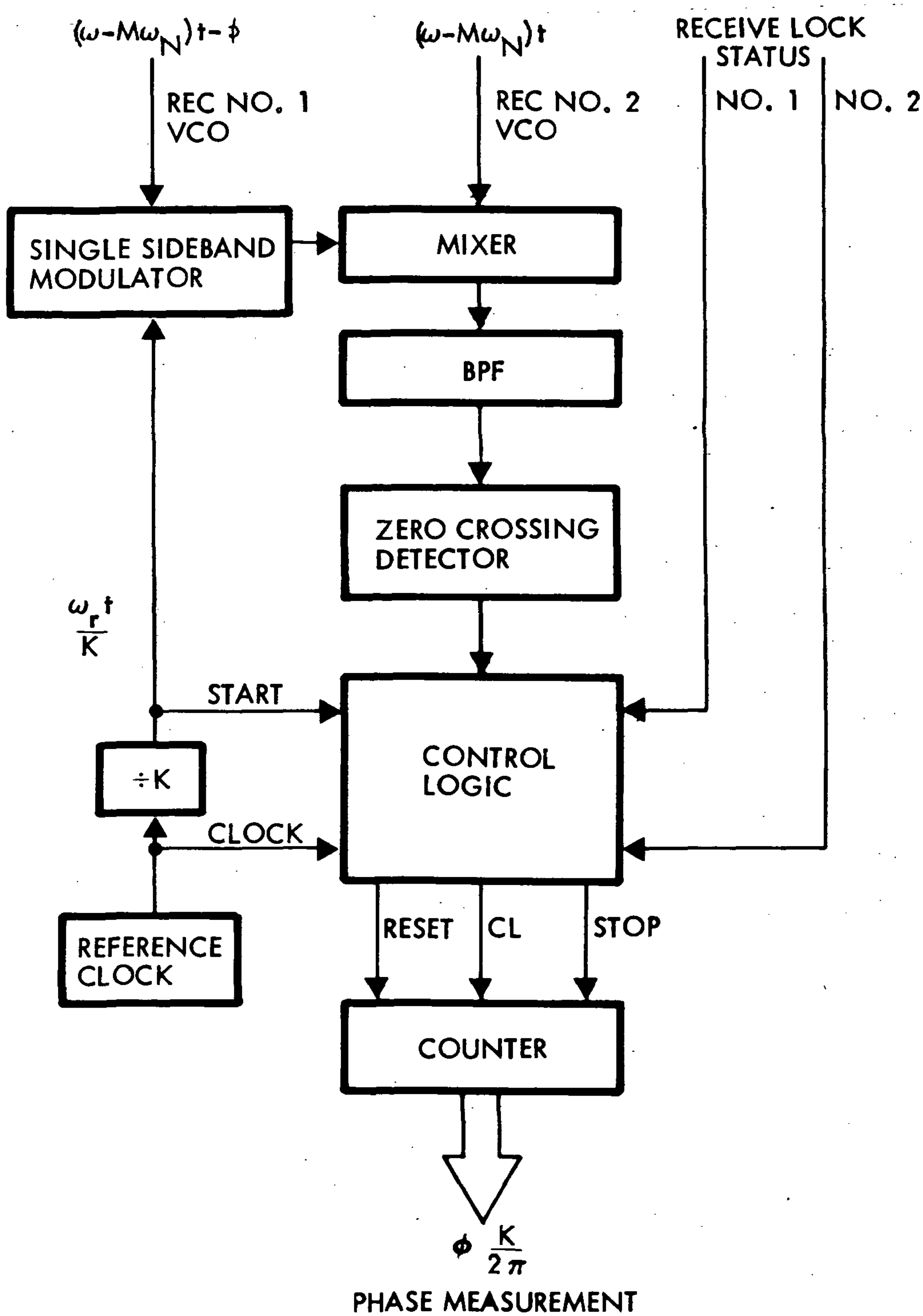


Figure 5-6. Baseline Block Diagram for 60 MHz Digital Phase Meter

SR&T TASK DESCRIPTION

Item 3. VHF Digital Phase Meter

Background

- This phasemeter is a key item, but is only used for the interferometer experiment
- It compares the phases of two 60 MHz signals derived from identical L-band receivers, and digitizes the difference to form a 13 bit measurement
- Commercial phase meters, in general, operate up to about 1 megahertz, with major interest (below 1 KHz) in servo analysis
- At higher frequencies we encounter the following problems:

  - Increasingly difficult to control phase linearity of detectors

- Available logic speed performance limits (measuring time x phase resolution product).

Objective

To develop a reliable and simple 60 MHz phasemeter.

SR&T Activities

- Evaluate and rank alternative circuit configurations
- Select preferred approach and complete detailed design

Baseline Concept

- Block diagram on opposite page (Figure 5-6) shows one possible configuration.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
	X		X	X	X	X	X	X		X	X	X

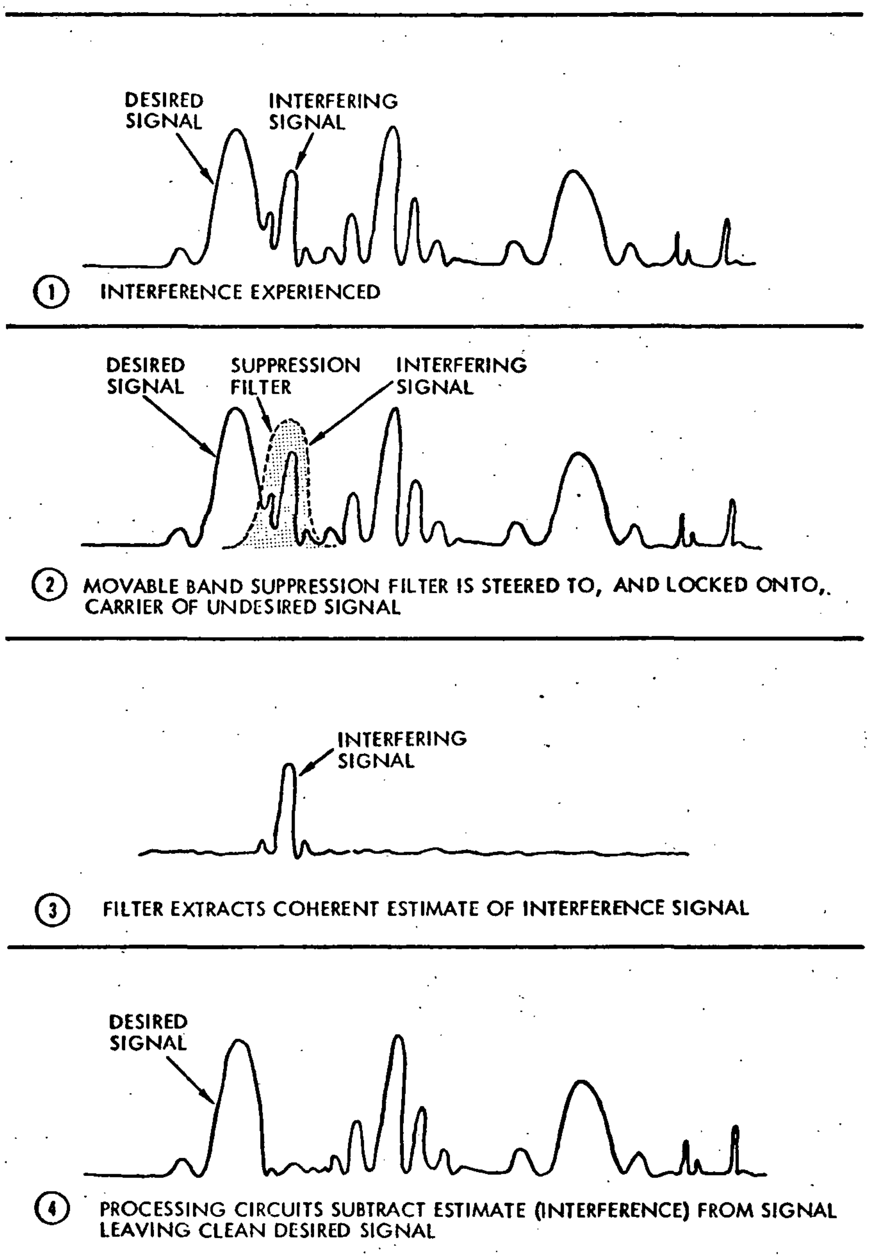


Figure 5-7. Sequence of Events in Use of Remote Control Filter

SR&T TASK DESCRIPTION

Item 4. Remote Control Filter

Background

- This filter is one of the concepts recommended for inclusion in the on-board data processing experiment
- The basic idea is also applicable, and would materially benefit the "terrestrial sources and noise" and the "communication relay" experiments
- The feasibility was established by TRW in television interference suppression tests on the Apollo program
- The operation of the signal filter in suppressing an unwanted signal is illustrated in Figure 5-7.

Objective

- Design and develop a considerably improved version of the original concept, incorporating the following features
  - Remote control of sweep and acquisition modes
  - A digital filter instead of lumped constants
  - A remote control of filter characteristics

SR&T Activity

Design - Development - Brassboard Fabrication - Remote Control - Demonstration - Revisions - Prototype Development and Fabrication

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
		X	X.		X	X	X	X	X	X	X	X

SOME PRELIMINARY CONCEPTS
FOR IMPLEMENTING ERP CONTROL

Down Link Modulation	Example of Possible Approach
PCM	• Provide high speed multichannel multiplexer with N times more ports than there are expected max system users • Control circuitry establishes power ranking for users • Each user's coded message is stored briefly and applied to several ports • No. of ports used per signal depends on desired signal ERP. Ground integration converts # of replications to effective SNR
FM	Each signal seized by phase lock loop processor which serves as translation (repeating) tool. Deviation made proportional to control signals

SR&T TASK DESCRIPTION

Item 5. Adaptive ERP Control

Background

- The required ERP of any one service depends on the local level of man-made noise at the receiving site, the data rate, and other variables
- A significant reduction in RFI can be affected by optimizing these ERP values
- Most satellites process user signals through common repeater circuitry and are designed to equalize the output power levels of the modulation components of each user channel.

Objective

- To study methods for independent control of the separate down-link signal powers
- To evaluate both remote and adaptive control schemes
- To define concepts, and generate block diagrams for satellite systems that allow such control

Technical Approaches

- Some suggested approaches for practical implementation are identified on the facing left-hand page.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X		X	X	X	X	X	X	X	X

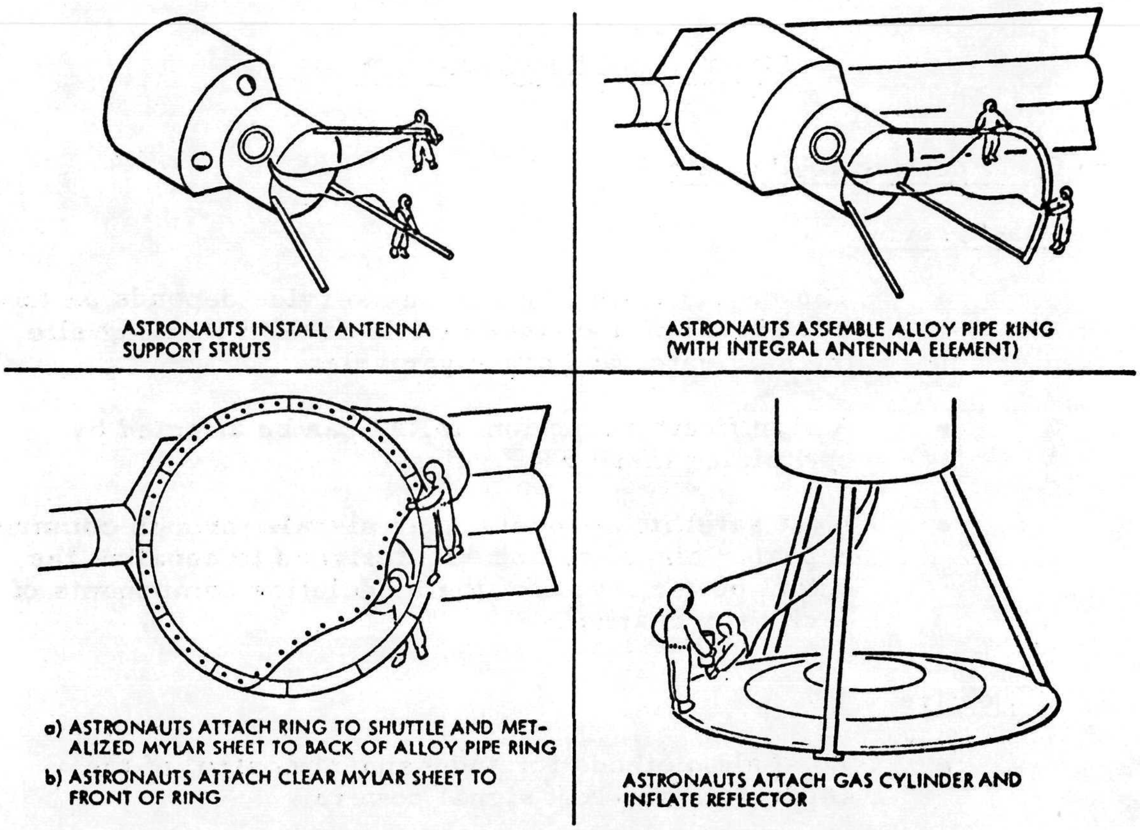


Figure 5-8(a)). Sequence of Events in EVA Assembly of Large Inflatable Membrane Dish

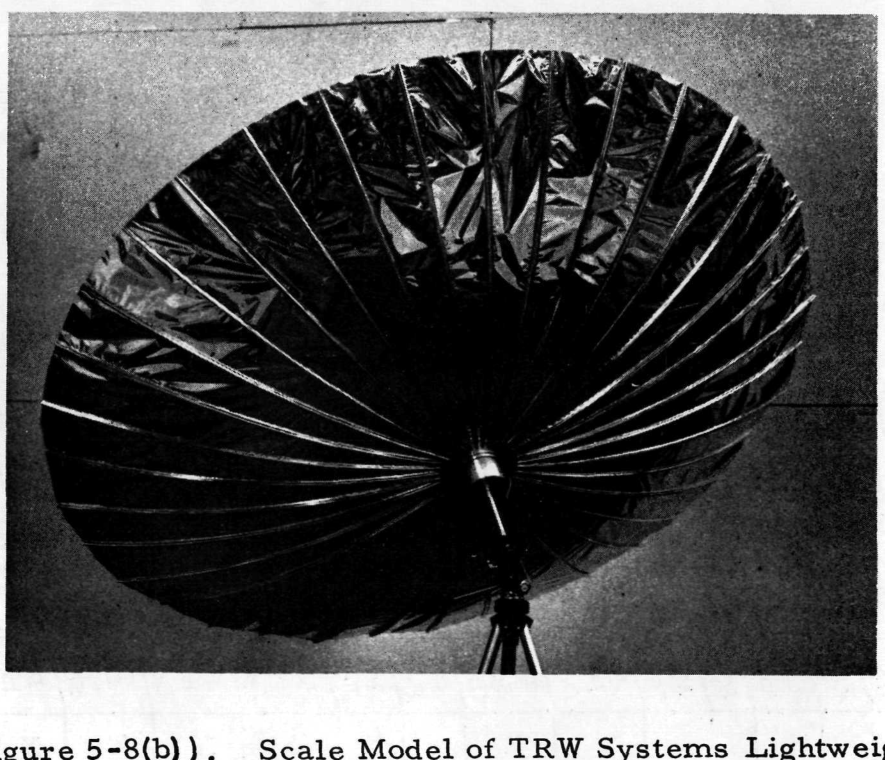


Figure 5-8(b)). Scale Model of TRW Systems Lightweight Deployable Aluminized Mylar Antenna Dish

Item 6. Large Deployable Reflector Technology

Background

- New Comm/Nav satellites will require narrow beamwidth
- The advent of the Shuttle will allow large structures to be assembled in space at modest cost (Figure 5-8(a))
- Several companies have fabricated medium sized inflatable designs ($D \approx 20$ ft.) and a variety of deployable parabolas. For example, TRW (see Figure 5-8(b))
- Inflatable building technology not well documented but a useful source of related information

Key Problems

- If reflector skin is made ultra thin to reduce weight, and supporting structure (formers) is minimized:
  - Reflector contour will depart from ideal shape, reducing gain, degrading beam shape, and increasing sidelobe levels
  - For large structures meteoroid induced punctures may necessitate developing self-sealing skin, open loop gas feed or foam filling.
  - Structure will suffer increased solar radiation deformation.
  - Focal length is function of gas pressure; pressure regulation may be necessary to cope with solar heating and diffusion loss.
  - Reflector membrane must be formed with seams; large reflectors have many, these perturb stress pattern so uniform radial force cannot provide parabolic shape
  - Randomized seam pattern may help, but computer analysis required to avoid costly cut-and-try methods

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C.V.T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X	X	X	X	X	X	X	X	X	X

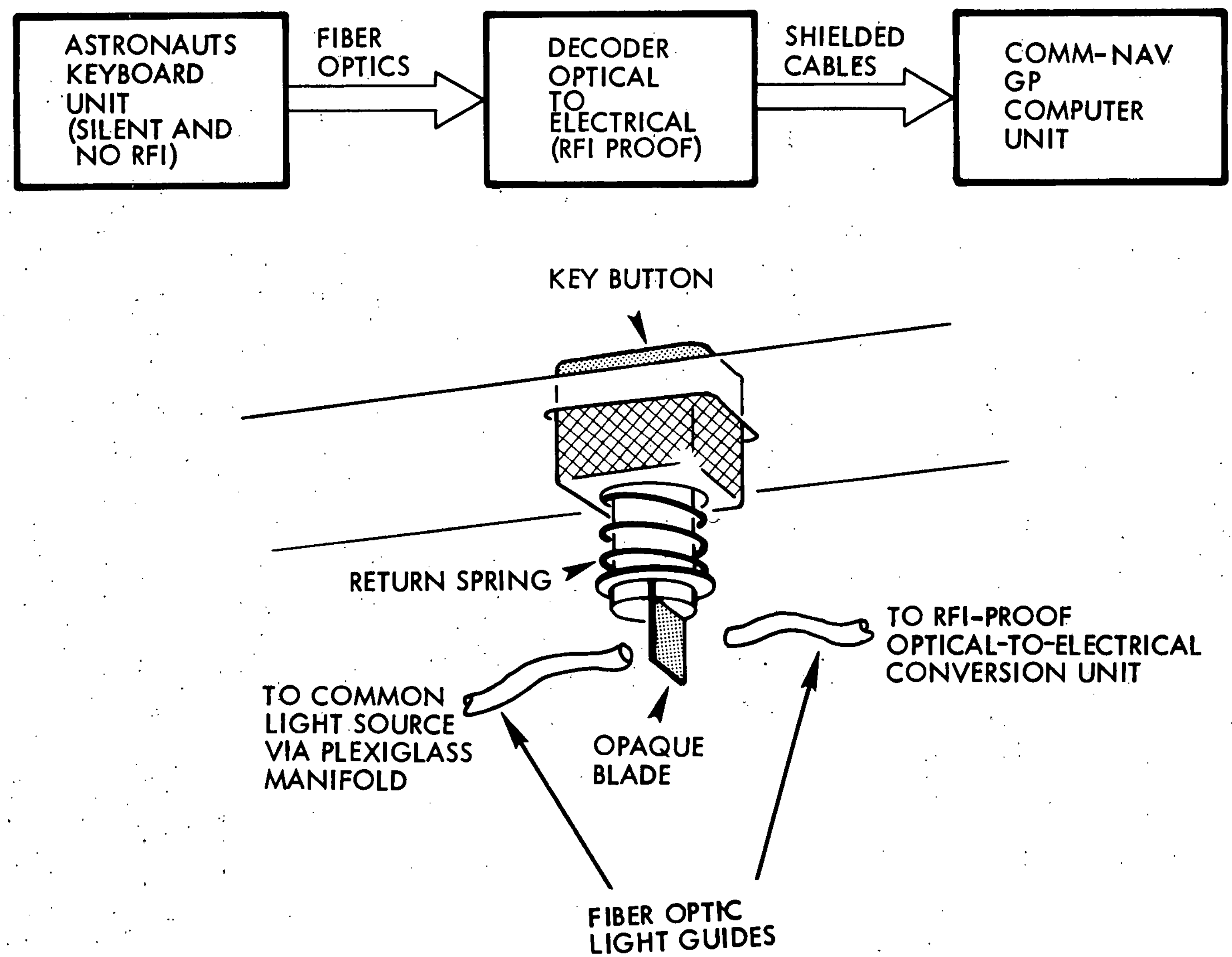


Figure 5-9. Suggested Silent Keyboard Implementation Concept

SR&T TASK DESCRIPTION

Item 7. Silent Keyboard

Background

- The proposed experiment control concept for the Comm/Nav Laboratory is to use a small G. P. computer in conjuction with an alpha-numeric operator keyboard (see also SR&T No. 15)
- Existing keyboards suffer from the following problems:
  - Excessive noise and heavy key action (mechanical coders)
  - Produce RFI, affecting results from other experiment
  - Non electrical hall-effect designs RFI sensitive and complex

Proposed SR&T

- Evaluate alternative approaches, specifically optical keyboard with fiber-optic link to RFI shielded console
- Perform initial product search to insure against re-invention
- Evaluate material and demonstrate feasibility
- Let contract for developing flight hardware

Technical Approach

- The suggested technical approach is illustrated in Figure 5-9 on the opposite page.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X		X	X	X	X	X	X	X	X	X	X

STATUS SUMMARY

- The majority of large element displays presently under development are based on monolithic gallium phosphide (GaP) substrates
- GaP is the most efficient light omitting material presently available and can be doped to provide a bright red or green output
- Matrix addressing is generally used to minimize the number of external connections that need be brought out from the semiconductor die
- The preferred semiconductor die structure is the "planar monolithic," comprising single pieces of semiconductor material, about 4 mils thick, requiring a surface finish of the order of ±1 mil.
- The substrate material can be made by:
  - Vapor epitaxial growth
  - Sliced from undoped ingot, and processed
- Liquid crystal devices, are extensively used for low cost pocket calculators but at present are only suitable for low density arrays.

SR&T TASK DESCRIPTION

Item 8. Solid State Display

Background

- Several of the Comm/Nav experiments require operator displays, and such equipments have been specified
- Existing displays incorporate cathode ray tubes which are fragile and constitute a serious health hazard to astronauts if they fracture from environmental stresses
- Under zero-G conditions glass particles and barium platino-cyanide screen material could be breathed by astronauts in a shirtsleeves environment

Proposed SR&T

- Evaluate present examples of solid state display, such as electroluminescent panels, light emitting diode matrices, piezo electric-laser scan combinations eldophor and similar approaches
- Select the preferred approach for Comm/Nav use
- Determine action needed to obtain hardware
- Initiate and monitor R and D

Status

- See Page 14a.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X		X	X	X	X	X	X	X	X	X	X

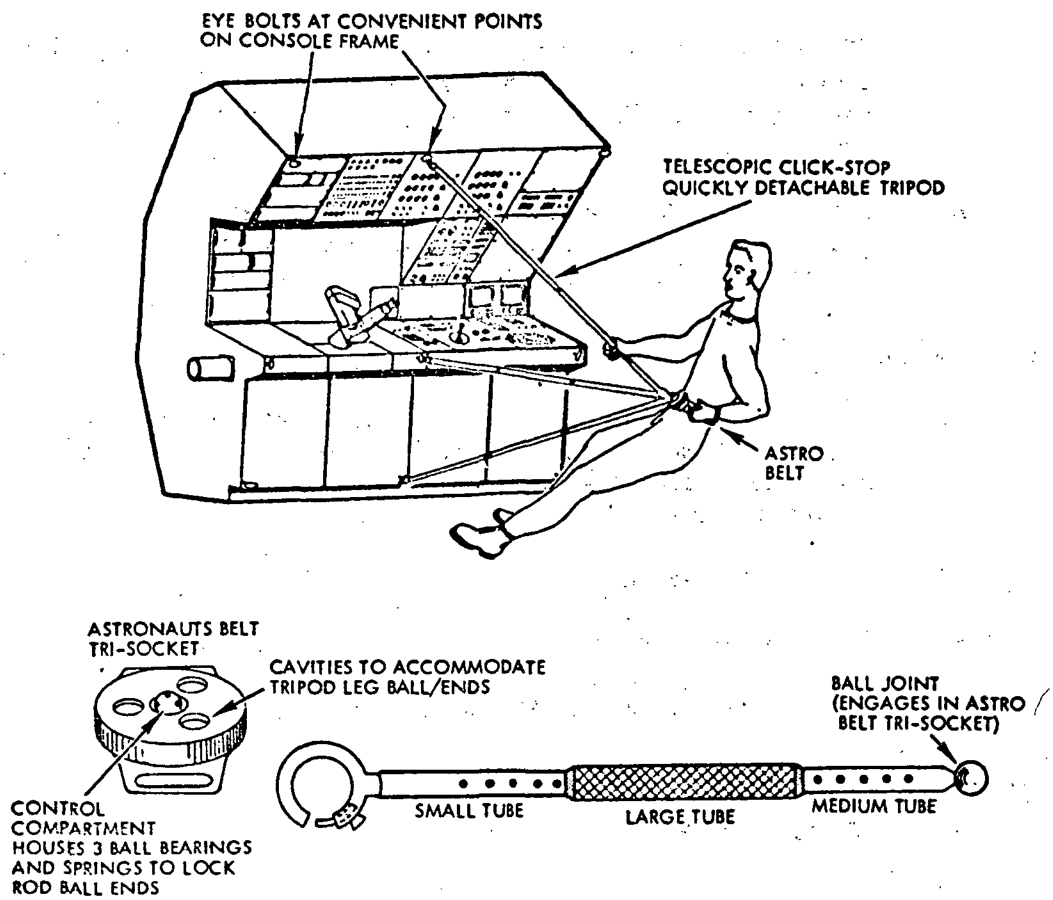


Figure 5-10. General Arrangement for Astronaut Location Rod

SR&T TASK DESCRIPTION

Item 9. Astronaut Location Rod

Background

- In order to operate the controls, and monitor the display associated with the laboratory the astronaut will need to maintain a position at the console
- Under weightless conditions astronaut arm and leg movement will cause undesired total body (reaction) motion
- To assist in maintaing the astronaut in a convenient posture relative to the console it is proposed to develop a location rod (or rod system) that assists the astronaut

Concept

- The initial concept comprises a light alloy or fiberglass tripod arrangement of three telescopic legs equipped with quick release miniature eyebolts. The apex of the tripod assembly would be attached to the astronauts belt via a quick release (such as parachute harness). The general arrangement and some preliminary design details are depicted in Figure 5-10.

Proposed SR&T

Consider, refine, define and develop such a device

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X		X	X	X	X	X	X	X	X	X	X

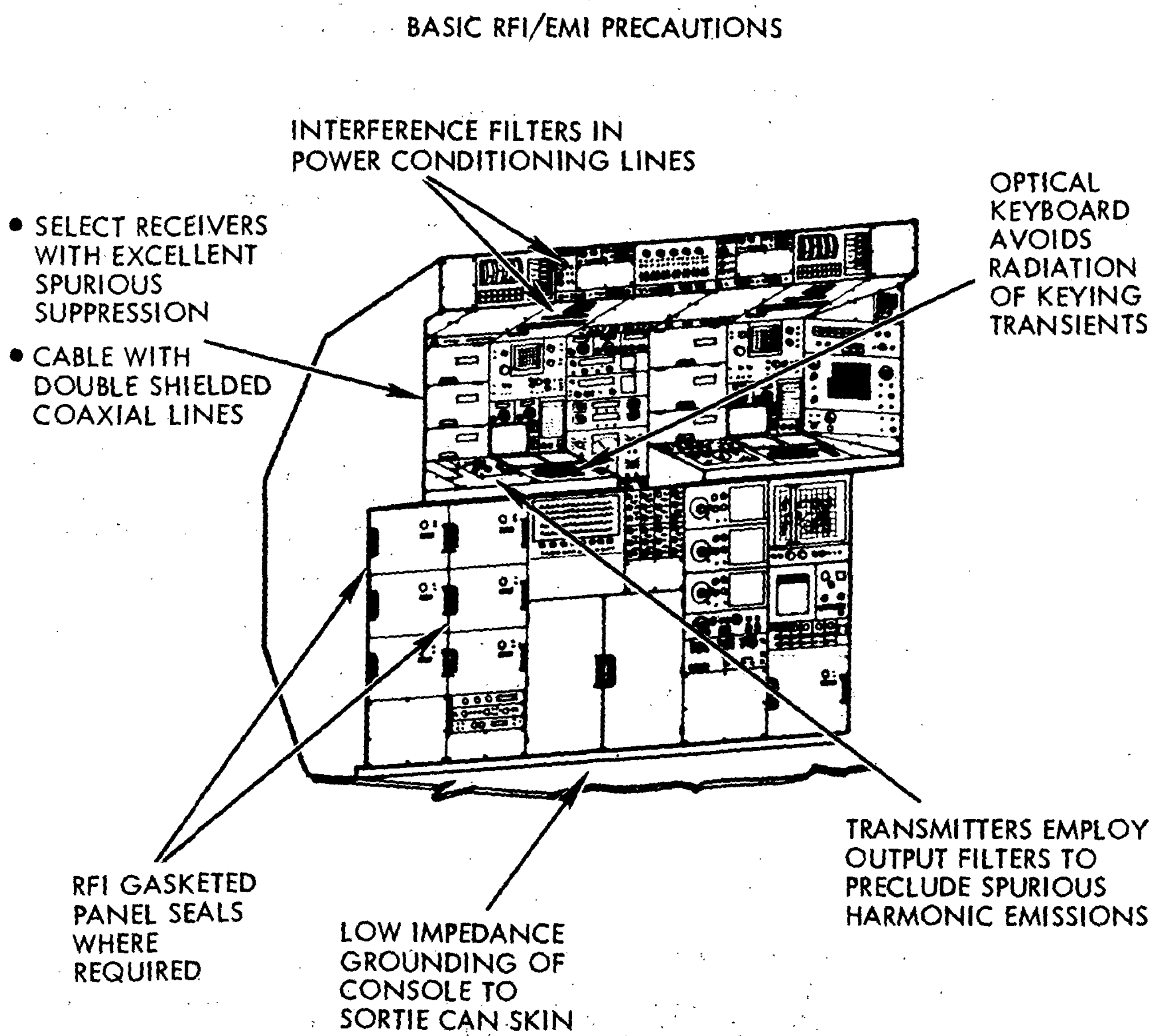


Figure 5-11. Some Typical Solutions and Alleviations of RFI/EMI Applied to the Comm/Nav Console

SR&T TASK DESCRIPTION

Item 10. RFI-EMI Protection for Sortie Can

Background

- Significant fraction of the measurements to be performed in the laboratory involve low level signals
- Whether these signals can be successfully detected, quantized and recorded will depend on the ambient noise and interference levels
- Typical solutions are illustrated in the accompanying sketch, Figure 5-11.

Concept

To enhance the statistics for success in these experiments it is proposed to run and SR&T task devoted to the RFI-EMI problem area

Proposed SR&T

- To combine the expected signatures of the equipment proposed for Early Lab use and synthesize a lab signature
- To evaluate the effect of such a background on each experiment
- To define the optimum compromise on RFI-EMI protection

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
	X	X		X	X	X	X	X	X	X		

SR&T TASK DESCRIPTION

Item 11. Commercial Equipment Translation

Background

- Because the proposed Comm/Nav Laboratory will involve a shirt-sleeve environment, regular commercial equipments that can withstand launch stresses are potential candidates.

- There presently appear to be three criteria for selection, these are:

  - Does the unit contain any toxic, flammable corrosive or similar materials

  - Does the unit incorporate any device that could poison or pollute the life support system such as CRTS, mercury relays, vacuum tubes radio-isotopes (trigger switches, transient supressors).

  - Is the unit safe from a physical standpoint, including sharp corners, rough welds, knife edges, high temperature points, compressed air exits, rotating and reciprocating machinery

Concept

A separate overall study of the proposed method for identification, investigation and translation commercial equipment to Comm/Nav laboratory use.

Proposed SR&T

A combined investigation and several sample exercises to yield recommendations.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
	X		X	X	X	X	X	X	X	X	X	X

SR&T TASK DESCRIPTION

Item 12. Improved Laser Detector

Background

- The laser communication, and optical propagation experiments require high efficiency, low noise detectors operable at a wavelength of 1.06 micron.
- The most attractive current candidate is the cross-field photo multiplier tube (XFPMT).
- Present examples of the XFPMT (e.g., RCA) are still in the research demonstration phase, and reared in "Bell Jars."

Proposed SR&T

- Investigate the status of existing XFPMT units in depth, and determine current evolution time table if undisturbed by Comm/Nav needs.
- Review alternative devices, and compare on basis of performance, astronaut safety, probability of success, and R&D cycle.
- Define the action and financial (contract) support required by NASA to convert this technology to Comm/Nav laboratory use.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X	X	X	X	X	X		X	X	X

SR&T TASK DESCRIPTION

Item 13. Tunable Laser

Background

- Existing high power lasers, used as transmitters in optical communication systems, operate over a relatively narrow bandwidth (typically 30 - 60 MHz).
- The wavelength of the carrier is established by the resonance phenomena and is intrinsic to the lasing material used (Argon, CO_2, Neon, etc.).
- For space applications, vehicle velocity causes a doppler shift in the received signal wavelength of the order of $\pm$ 10 GHz.
- For optimum detection it is necessary to employ an optical hetrodyne arrangement analogous to that of a radio receiver.
- A tuneable, optical, local oscillator is required for this arrangement.
- The suggested candidate is the lead telluride single crystal P-N junction injection laser recently reported by Lincoln Labs.

Proposed SR&T

- Investigate the potential applicability of this and other injection lasers to the Comm/Nav optical experiments.
- To define a preferred local oscillator and pursue its development.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X		X	X	X	X	X	X		X	X	X

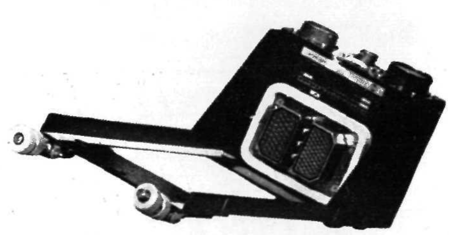
AVIONIC EQUIPMENT RACK SYSTEMS

Brief History

- Initial work by civil airline representatives and Aeronautical Radio, Inc. (ARINC), developed specifications for ATR system. (1938-1940).
- In 1947 RTAC committee (SC-20) tried unsuccessfully to discard ARINC system and substitute British version designed by Society of British Aircraft Constructors (SBAC).
- In 1953 ARINC staff proposed to combine ARINC-ATR and SBAC systems to form a "B" International.
- The U. S. Military services made proposals for changing ARINC-ATR and finally produced MIL-U-25900, an independent specification, in May 1958. This spec was subsequently recalled and "died."
- Although the British SBAC racking scheme was acknowledged (by ARINC) to be better and more flexible, increasing word usage of the ARINC-ATR forced UK changeover in mid 1958.
- The U. S. -developed ATR packaging system is now universally used for aircraft equipment.

Typical Multi-Unit Installation of Avionic Equipment

Representative Panel Mounted VHF Transceiver



Single Equipment ATR Tray Showing Integral Signal and Power Connectors

Typical Avionic Receiver Unit

Figure 5-12.

SR&T TASK DESCRIPTION

Item 14. Improved Rack-Tray Equipment Accommodation

Objective

To define an improved mechanical structural system to accommodate all electrical, electronic and related equipments of Comm/Nav experiment payload.

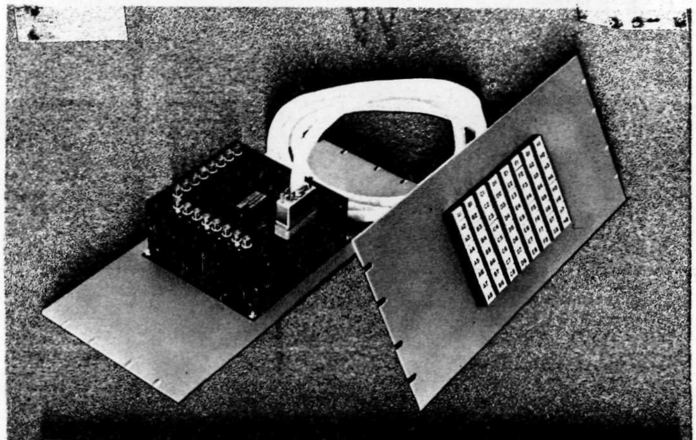
Background

- The aircraft industry has developed a standard system of mechanical components called "ATR" for accommodating electronic equipment in aircraft (see Figure 5-12)
- The system includes standardized skeleton frames that attach to the aircraft skin, shock mounts, equipment trays, cases, quick release locking devices, etc.
- The system components are fabricated of light alloy material using folded, dished and braced perforated sheet to maximize the strength to weight ratio.
- The system is proven, components are all readily available and it offers major improvements in payload efficiency. It is much cheaper than custom spacecraft design and drastically lighter than regular 19 inch ground equipment rack systems.

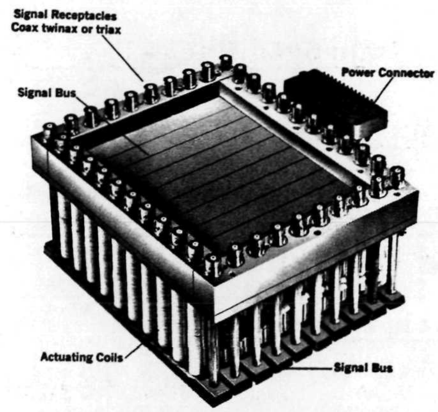
SR&T Action

- To investigate the use of this system for Comm/Nav.
- To investigate alternative materials, optimum modifications, extra items, etc.
- To evaluate the avionic equipment already available and compatible with ATR.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
	X		X	X	X	X	X	X	X	X	X	X



8 x 8 Matrix with Lighted Pushbutton Panel



View of 10 x 10 Modular Matrix (less enclosure)

WHAT IS A PIN SWITCH?

- A P.I.N. semiconductor sandwidge structure diode that exhibits stable very low impedance (virtually a short circuit) when "ON" and a very high impedance (virtually an open circuit) when "OFF".
- It can be flipped from the "ON" to the "OFF" condition by applying low power control signals.
- It features extreme operating speeds.

WHAT REMAINS TO BE DONE?

- Integrate diodes with control circuits to hold selected condition.
- Find means of large scale integration or an allied extension of number of ports.
- Reduce unit cost, now about $300/unit.
- Improve matching reflections (VSWR).

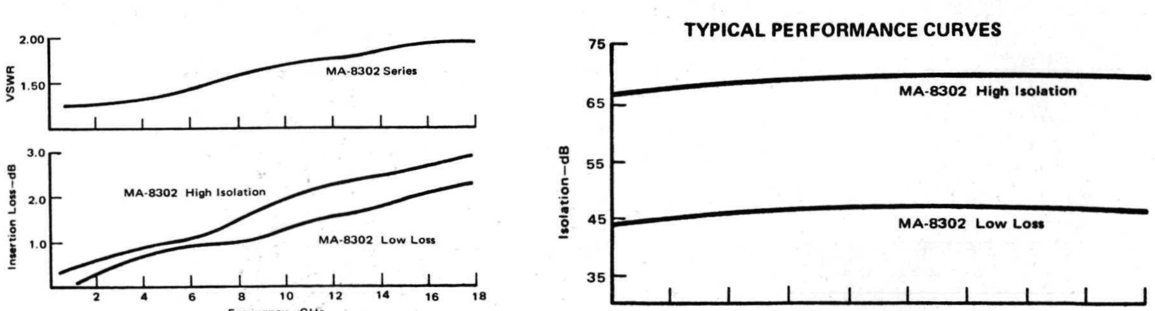


Figure 5-13. Typical Coaxial Matrix Switches and Available Performance from Recent Pin Diode Units

Item 15. Signal Switching Matrix

Background

- To provide the essential equipment interconnection versatility needed for a true laboratory, we must provide the means to quickly reconfigure equipment items.
- A plug and socket approach is neither reliable nor convenient. Special care must be taken to avoid the sparking associated with current interruption electric shock, corona, and fire hazards.
- Manual switching is complex, limited in flexibility, slow and prone to human error.
- The proposed approach is to use an operator keyboard to call up experiment configurations stored in the G.P computer memory (or magnetic tape).
- Keyboard would also serve to modify details of any configuration (temporary or permanently).
- The configurations would be implemented by the memory cell conditions assigning appropriate conditions to switches located in the main equipment consoles. Typical switches and performance Figure 5-13.
- To implement this scheme will require the development of new, high performance, lost cost, switching matrices.

Proposed SR&T

- Evaluate the switching needs across all 18 experiments, and identify performance objectives.
- Investigate performance and cost basis for existing computer controlled, high isolation, UHF and microwave switches, specifically pin diode solid state devices.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
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PRINCIPLE OF MEASUREMENT

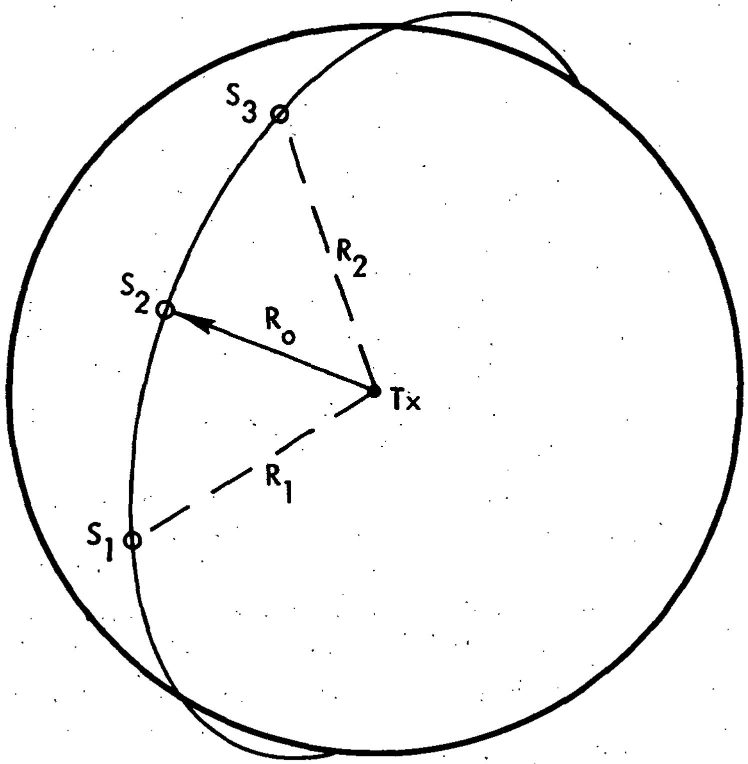

Figure 5-14. Illustrates a Flyover Situation

- S_1, S_2, and S_3 are sequential positions of Orbiting Laboratory, and T_x is location of terrestrial transmitting site.
- The motion of the laboratory relative to point T_x causes any received signal to suffer a Doppler frequency shift, passing through a zero shift at the closest approach condition (R_o), denoted as S_2.
- For a given orbit or carrier frequency, the Doppler frequency shift versus time characteristic is a unique function of the location of the site (T_x) relative to the satellite sub-track.
- By making a series of frequency measurements in the laboratory, the location of T_x can be established.
- Inherent mirror image can be resolved by combining data from two displaced orbits.

SR&T TASK DESCRIPTION

Item 16. Improved Doppler Analysis Software

Background

- It is proposed that doppler time history analysis be used as a means of locating the position, and identifying terrestrial sources of interference. (Figure 5-14)
- This method has been previously evaluated for balloon position location in the "OPLE" and other programs.
- The main disadvantages are:
  - Cost and speed of accurate computer computations
  - Lateral ambiguity of single pass result
- Because the method is passive, free loading on known terrestrial sources, it is of considerable interest for navigation purposes as well as the immediate use as a supplement to the terrestrial sources of interference and noise experiment.

Proposed SR&T

- Re-examine the work of Laughlin, Arndt, et al and evaluate the potentially realizable accuracy as a function of laboratory and ground source transmitter, and Comm/Nav laboratory oscillator stabilities.
- Evaluate various processing algortihms and develop faster software to reduce the processing delay and cost.
- The innovation sought is akin to the fast Fourier transform.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C.V.T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X					X	X			

SR&T TASK DESCRIPTION

Item 17. Efficient Antenna for VLF

Concept

- The ELF/VLF Experiment will involve reception and transmission of radio signals at frequencies in the range of 10 KHz.
- Key problem area is that of providing an efficient antenna at such a low frequency.
- Two schemes are common in terrestrial use, ultra long wires and ferrite rods (loopsticks).
- For space applications we must also minimize size and weight and provide methods for initial dispensing and subsequent locational stability.
- Consideration of these topics has led to the identification of a list of candidate concepts that require comparative evaluation.

Proposed SR&T

- Evaluate the feasibility and expected performance of the following concepts:
  - Long wire antennas (L = zero—λ/4)
  - Ferrite rods antennas and arrays of rods
  - Large loop antennas
  - Plasma, isotope, or conductive particle trails
  - Composite conductors; e.g., foam, fiber-reinforced wire, micro-wall tubing.
- Review the design of current long antenna deployment accessorites, such as De Havilland "Stem." Establish approach for lengths of up to five miles or limit length.
- Evaluate the performance of basic materials including: conductivity, density, strength, cost, toxicity, etc.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C.V.T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X	X	X	X	X	X		X	X	X

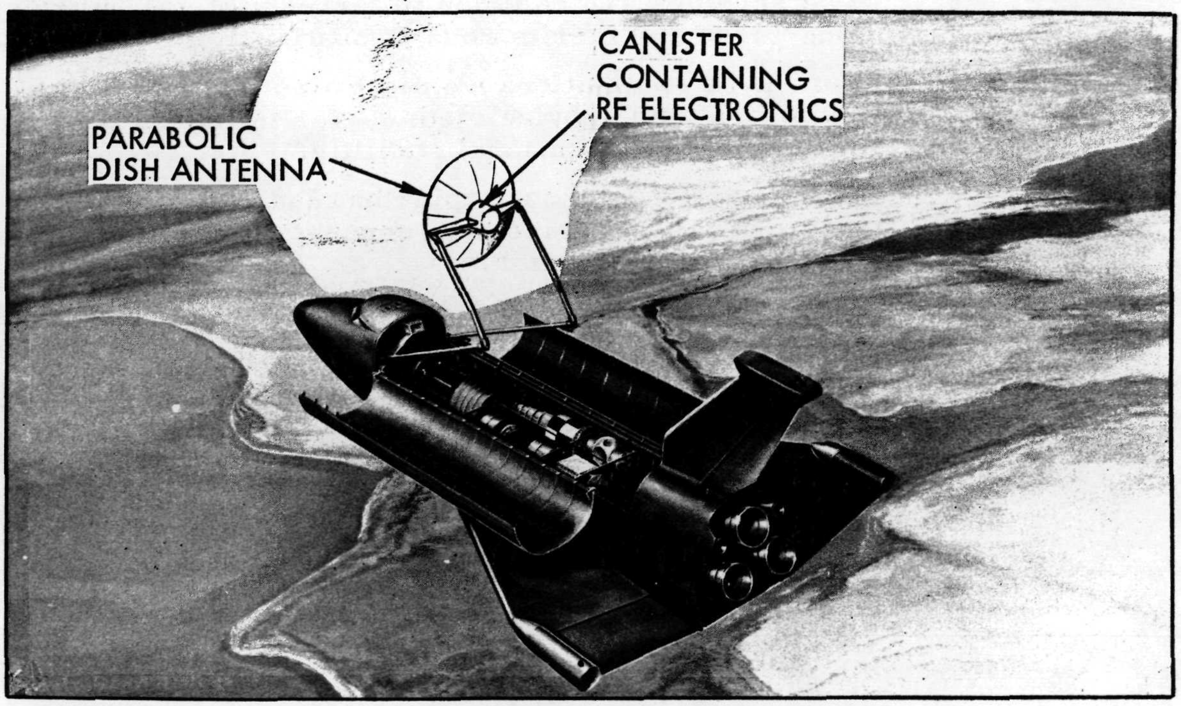

Figure 5-15. Artist's Illustration of Proposed Manipulator Actuated RF/Antenna Package

SR&T TASK DESCRIPTION

Item 18. Adaptation of EVA Manipulators for Comm/Nav Antenna Deployment

Background

- For most of the experiments considered thus far, each antenna or optical sensor is provided with a "personal" deployment and/or tracking pedestal.
- There appears a strong probability that manipulator arms for EVA activities will be incorporated in the Shuttle for recovering unmanned satellites.

Concept

- The proposed concept is to use these manipulators as the deployment and tracking element for any Comm/Nav payload antenna or sensor as shown in Figure 5-15.

Benefits

- The manipulator could probably replace almost all the mounts and provide these advantages:
  - Better performance because cost shared
  - Safer, only two deploying elements
  - More versatile orientation possible
  - New antenna head ends or sensing packages need only be placed in retrieval area.

Proposed SR&T

- Evaluate all Comm/Nav pointing and deployment plus experiment time lines.
- Investigate performance available from anticipated manipulator designs.
- Define preliminary interface. Fabricate and demonstrate.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C.V.T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X	X	X	X	X	X	X	X		

SR&T TASK DESCRIPTION

Item 19. Improved Kalman Filter for Post-Acquisition Data Accuracy Enhancement

The performance of the landmark tracking, interferometer, and terrestrial sources (Doppler location aspect), narrow beam tracking, and laser ranging experiments could all be significantly upgraded by statistical data filtering using a Kalman Technique.

These experiments involve the acquisition of sequential or continuous data on the position of some target. This data is corrupted by noise and can be improved by filtering.

In recent years (e.g., 1969),* improved techniques have been reported that materially reduce the computer processing time for accomplishing the required matrix arithmetic.

The proposed task is aimed at furthering this progress and focusing it on the special problems and specific data situations associated with the Comm/Nav Laboratory mission.

*R. B. Merrick (NASA Ames), "A Simplified Kalman Estimation for an Aircraft Landing Display," AIAA Paper 69-944.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X				X	X	X			

CONCEPT NO. 1

CINE-CAMERA TURRET CONCEPT

FOUR RF HEADS ON WHEEL

ANY ONE UNIT CAN BE POSITIONED TO DRIVE DISH VIA COMMON SUB-REFLECTOR

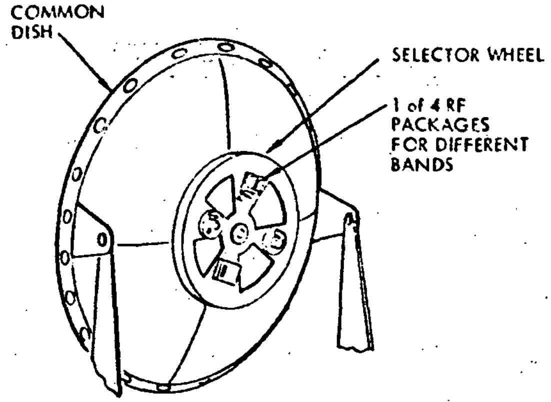

Figure 3-16(a)

CONCEPT NO. 2

FOUR INDEPENDENT LIGHTWEIGHT ARMS ARE HINGED AT DISH EDGE

LINEAR ACTUATORS PERMIT ANY ONE ARM TO FOLD ROUND TO FRONT OF DISH INTO FOCUS POINT

EACH ARM CARRIES A DIFFERENT ANTENNA & RF HEAD OR CABLE

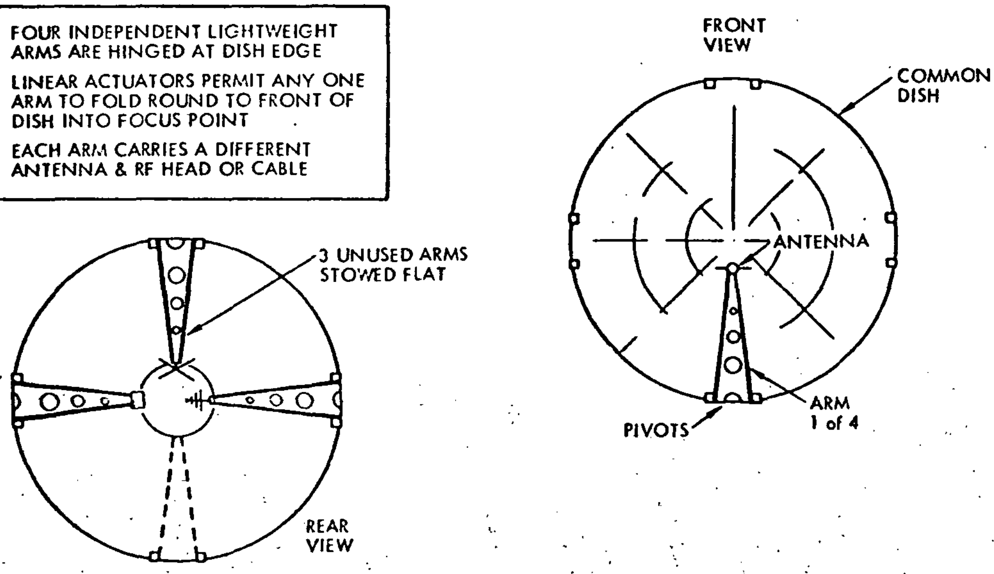

Figure 3-16(b)

SR&T TASK DESCRIPTION

Item 20. Interchangeable Microwave Packages and Common Reflector

Background

- Current spacecraft use each antenna over a relatively small frequency range.
- At microwave frequencies, waveguides used for feed system have a limited frequency band.
- To achieve desired antenna pattern, waveguide feed in use must be precisely located in dish.
- Dish surface finish specification becomes progressively more critical as operating frequency is raised.

Concept

- To develop an antenna/microwave head and packaging concept that will allow convenient EVA substitution.
- To extend this concept, based on initial results, to a remote controlled turret, see Figure 3-16(a), or equal arrangement, see Figure 3-16(b).

Technical Problems

- A coupling system that is simple enough for safe and speedy EVA changes, but:
  - Provides precise component location
  - Avoids unintentional cold welding (freezing)
  - Covers a wide frequency range
  - Does not entail several men for EVA, or complex jigs and tools.

R&D Objectives

- Define microwave head ends for 10 through 200 GHz frequency range.
- Investigate "mating" techniques and dish parameters.
- Design preliminary package.
- Investigate and develop turret concept.

Literature Search and Bibliography Accumulation	Problem Analysis	Computer Synthesis and/or Analysis	Preliminary Design	Materials and Fabrication Methods Survey	Breadboard & Test Portions of System Document Results	Prepare Preliminary Specifications and Drawings	Fabricate Brassboard Feasibility Model	Perform Electrical Tests & Document	Carry Out Conceptual Verification and Testing (C. V. T.)	Perform Environmental Tests and Document	Define Contract Type Prepare Procurement Specifications	Prepare & Issue RFP to Solicit Industry Contracts
X	X	X	X	X	X	X	X	X	X	X	X	X